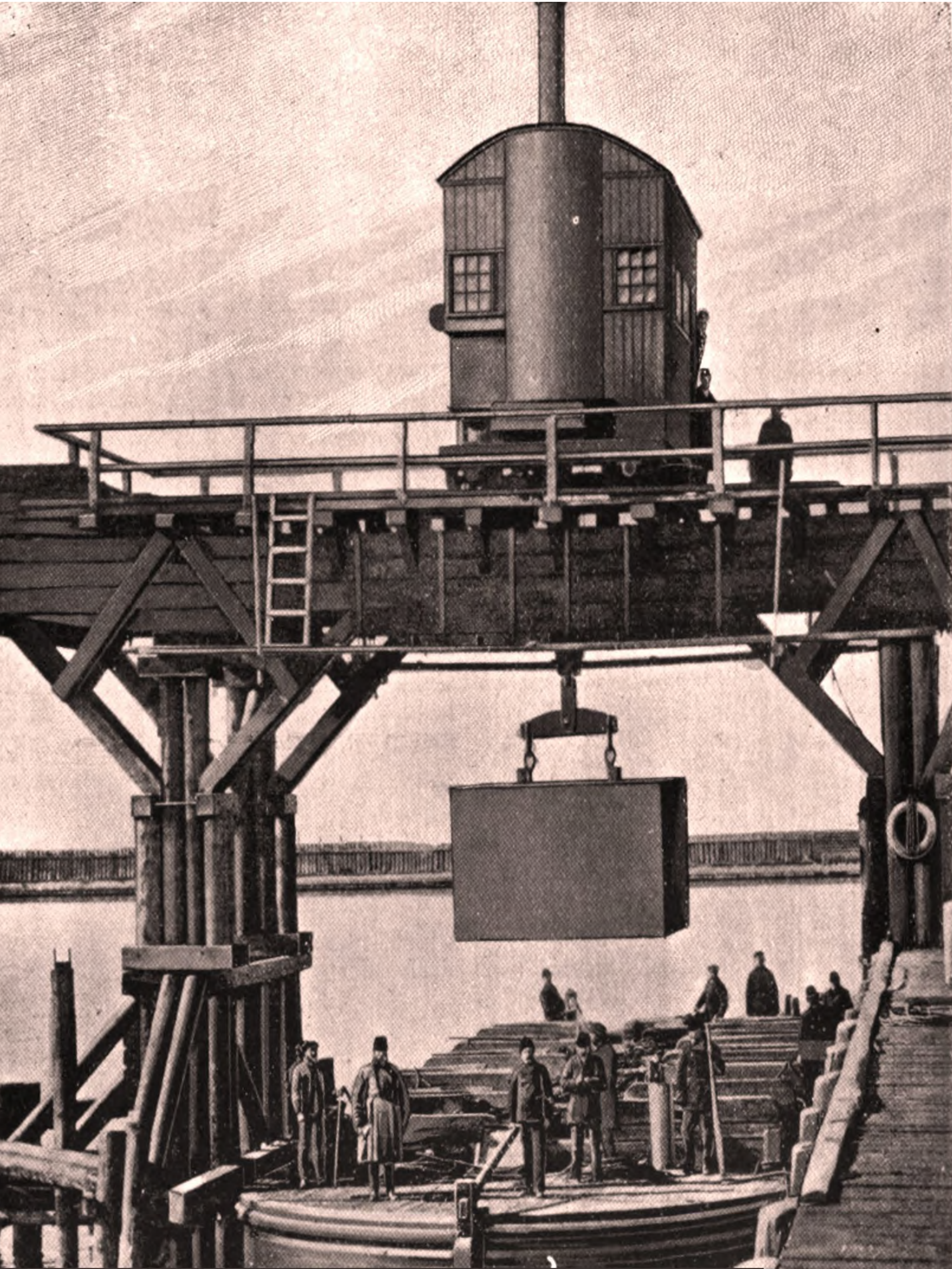


Appleby's Illustrated Handbook of Machinery : Contractor's plant and ...

Charles James Appleby

APPLEBY'S ILLUSTRATED HANDBOOK OF MACHINERY.

SECTION V.

STEAM AND ELECTRIC PLANT

EMPLOYED IN

THE CONSTRUCTION AND EQUIPMENT OF HARBOURS, DOCKS, CANALS, RAILWAYS, &c.

EXCAVATORS, DREDGERS, CONVEYORS AND PLANT FOR HANDLING COAL AND OTHER MATERIALS.

IRON STRUCTURES, BRIDGES, AND APPLIANCES FOR ERECTION.

QUARRYING AND STONE WORKING MACHINERY.

NOTES, TABLES AND MEMORANDA.

BY

C. J. APPLEBY, M. Inst. C.E.,

[JESSOP & APPLEBY BROS. (LEICESTER AND LONDON), LIMITED],

22, WALBROOK, LONDON, E.C.

Telegraphic Address—"**MILLWRIGHT, LONDON.**"

A B C, MOOREING'S, THE A1, AND APPLEBY'S CODE. PAGES i. to iv.

PRICE 5/-

LONDON:

E. & F. N. SPON, LIMITED, 125, STRAND.

NEW YORK:

SPON & CHAMBERLAIN, 12, CORTLANDT STREET.

1903.

APPLEBY'S HANDBOOK OF MACHINERY.

THE Edition published in 1869, and several reprints of it, having been exhausted, a NEW EDITION (of which this section forms a portion) has now been completed; and for the convenience of those who desire information on specific subjects, but not on all those treated, the book is divided into six sections, each of which, bound in cloth, may be obtained separately as follows:—

SECTION 1.—PRIME MOVERS.

STEAM, GAS AND AIR ENGINES, BOILERS, DYNAMOS, MOTORS, TURBINES, ETC.

Price 3/6.

SECTION 2.—HOISTING MACHINERY.

WINDING ENGINES, HYDRAULIC, STEAM, ELECTRICAL AND HAND CRANES.
WINCHES, JACKS AND OTHER LIFTING APPLIANCES.

Price 3/6.

SECTION 3.—PUMPING MACHINERY.

PUMPING ENGINES, CENTRIFUGAL, STEAM, ELECTRICAL AND HAND PUMPS.

Price 3/6.

SECTION 4.—MACHINE TOOLS AND ACCESSORIES.

FOR WORKING METALS, WOOD, ETC.

Price 3/6.

SECTION 5—CONTRACTORS' PLANT AND RAILWAY MATERIALS.

INCLUDING MACHINERY AND APPLIANCES FOR THE CONSTRUCTION AND EQUIPMENT OF HARBOURS, DOCKS, RAILWAYS AND OTHER WORKS, NOTES, MEMORANDA AND TABLES.

Price 5/-

SECTION 6.—MINING, COLONIAL AND MANUFACTURING MACHINERY.

FOR TREATING ORES, CORN, COFFEE, RICE, SUGAR, COTTON, AND OTHER PRODUCTS, OIL MILLS, ICE MAKING, DISTILLING, ETC.

Price 3/6.

The subject matter has been entirely re-written, and is illustrated by a large number of Engravings which (for the most part) represent work carried out by the Author's Firm.

The arrangement is intended to be in a handy form for reference, useful alike to engineers, users, and to purchasers of machinery and of materials connected therewith.

The approximate prices are based on the present cost of materials and of labour, and these—as well as details of design and proportions—are necessarily subject to modification without notice.

Some data is given with reference to the cost of working, motive power required and work performed; also approximate weights and measurements, so that the results obtainable and the total cost including freight, import duties, etc. may be roughly estimated. The cost of packing for shipment and delivery to docks varies with the nature of the packing required and the destination, the rates given being the average as nearly as they can be determined.

PREFACE.

The aim of the present volume is to direct attention to some matters for consideration in connection with works to be undertaken, and to materials, methods, and appliances which have been successfully employed in constructive operations varying widely in character and magnitude.

As improvements in design and construction are constantly being made, the illustrations and descriptions now published should be regarded as typical and not necessarily representing developments which may hereafter be generally adopted.

It will be evident that most of the appliances referred to are capable of adaptation to conditions differing from those specifically mentioned, and if modifications should be desirable, these will probably tend, only, to higher efficiency and lower working expenses.

The Tables and Memoranda incorporated in this volume (originally intended to form a separate section) are limited to those which will be of service to purchasers and users of machinery, rather than to designers and constructors, who now have access to so many excellent text books relating to the different branches of engineering practice.

In conclusion, the writer sincerely thanks the friends who have kindly placed at his disposal much valuable and, hitherto, unpublished information with reference to work carried out under their direction, aided (in many cases) by appliances for the construction or arrangement of which he may have been, to some extent, responsible.

London,
1903.

APPLEBY'S COPYRIGHT CODE.

FOR CORRESPONDENCE BY TELEGRAM.

TELEGRAPHIC ADDRESSES RESPECTIVELY: "JESSOP, LEICESTER." "MILLWRIGHT, LONDON."

The code numbers are for use in case a repetition of the telegram may be necessary.

ENQUIRIES AND QUESTIONS.

191290	**Taaier** ..	...Telegraph how soon you could ship the following, viz..................
191291	**Taaiheid** ...	...Reply, by letter, how soon you could ship the following, viz............
191292	**Taainagel** ...	Telegraph at what price, packed and delivered f. o. b English port you could supply and ship the following, viz ....
191293	**Taalboek** ..	Reply, by letter, at what price, packed and delivered f. o. b. English port, you could supply and ship the following, viz...............
191294	**Taaldeel** ...	Telegraph how soon and at what price, packed and delivered f. o. b you could supply and ship the following, viz... ....
191295	**Taaleigen** ..	Reply, by letter, how soon and at what price, packed and delivered f. o. b. English port, you could supply and ship the following, viz...............
191296	**Taalfout** ..	...Telegraph name of vessel by which you have shipped.
191297	**Taalgebrek**	We learn that the..............with your goods on board has been lost. Shall we replace?
191298	**Taalgids** ...	...Telegraph, at my expense, how soon my order wil be despatched?
191299	**Taalgrond**...	...Reply, by letter, how soon my order will be despatched.
191300	**Taalkundig**	...Do you wish us to proceed with order?
191301	**Taalman** ...	...Will you leave matter to our discretion?
191302	**Taalregel** ...	...When will remittance be sent for £.........
191303	**Taalschat** ...	...Send us a complete tracing of...........
191304	**Taalteeken**	...Send us a photograph of...........
191305	**Taalvitter** ...	..Send us a complete estimate for the following...... .....
191306	**Taalvriend**...	Prepare design and send tracing and estimate including delivery f. o. b. for...........
191307	**Taalwet** ...	...Can you alter the goods to our order as follows...........
191308	**Taalzifter** ...	...How soon can you deliver?
191309	**Taanbloem**	...Have you in stock?
191310	**Taartblik** ...	...A reply by wire is requested.
191311	**Taarten** ...	...A reply by first mail is requested.

ORDERS AND INSTRUCTIONS.

By Sailing Vessel.	Steamer.	Mail Boat.	
191312 **Taartepan**	191313 **Taartjes**	191314 **Taartkoek**	Please supply and ship as soon as possible the following goods, engaging freight and insurance, free of particular average.
191315 **Tababocca**	191316 **Tabacalero**	191317 **Tabacales**	Please supply and ship as soon as possible the following goods, engaging freight and insurance, free of all risks, if latter is possible.

191318	**Tabaccasse**	...No part of the machine must weigh more than........... cwts.
191319	**Tabacchi** ...	...We leave matter to your discretion.
191320	**Tabacomane**	...Preferring them in the order named.
191321	**Tabacosas**...	...Payments may be made by...........
191322	**Tabacoso** ...	. Payments will be made by........... Arrange terms with that firm.
191323	**Tabagie** ...	...Terms will be as before
191324	**Tabagique**...	...Remittance is delayed until...........
191325	**Tabahia** ...	. Draw on us at sight for £..........
191326	**Tabakasche**	...Draw on us at...........
191327	**Tabackbau**	...Await instructions for shipment.
191328	**Tabakbeize**	...Replace with all possible despatch.
191329	**Tabakdampf**	...Duplicate our order of..........
191330	**Tabakkorb**	. Repeat our order for...........
191331	**Tabakladen**	...Repeat our last order.
191332	**Tabakqualm**	...Await our letters before proceeding.

Orders and Instructions—*Continued.*

191333	**Tabakrauch**	...Same pattern or quality as before.
191334	**Tabakreibe**	...The same as you last supplied.
191335	**Tabakrolle**	...Same as supplied by you in............
191336	**Tabaksblad**	...Same as supplied by........... in............
191337	**Tabaksbouw**	...Same as supplied to............in............
191338	**Tabaksland**	...Draw on us for £............at the following number of days from sight.
191339	**Tabakspijp**	...Please deliver at once.
191340	**Tabaksrook**	...Please deliver next week.
191341	**Tabakstube**	...Must be inspected by............
191342	**Tabaksvat..**	...Ship at once.
191343	**Tabaksveld**	...............has been irreparably damaged send another.
191344	**Tabakszak**	....has been lost replace it immediately.
191345	**Tabaleabau**	...Please send by next mail certificate for............
191346	**Tabaleara ...**	...Prepare for delivery at once.
191347	**Tabaleos ...**	...Wanted for immediate delivery.
191348	**Tabalhiom...**	...The makers were (are)............
191349	**Taballiado...**	. As described in Appleby's Handbook of Machinery, price £.........

ANSWERS, &c.

191350	**Tabanca ...**	..Freight will add about............per cent. to the f.o.b cost.
191351	**Tabanidae...**	...The machine will weigh about............cwts.
191352	**Tabaquear...**	...The total weight will be about.......... tons.
191353	**Tabaqueiro**	...The total measurement will be about............cubic feet.
191354	**Tabaqueras**	...No part of the machine will weigh more than........... cwts.
191355	**Tabaqueurs**	...The machine is finished.
191356	**Tabaquista**	We can supply you with goods, as per your enquiry, at the following *net* price.
191357	**Tabardelha**	...Please telegraph credit with some English Bank for order just received.
191358	**Tabarder ...**	The credit opened with the Bank is too small; please to telegraph further credit for £............
191359	**Tabardilho...**	..We cannot execute order on other terms.
191360	**Tabarzet ...**	...We have remitted you by letter £............
191361	**Tabatiere ..**	...Cash will be paid against Bill of Lading by............
191362	**Tabaxir ...**	...Machinery is shipped by steamer.
191363	**Tabbaard ...**	...Machinery will be shipped by steamer.
191364	**Tabbaoth ...**	...Machinery is shipped by sailing vessel.
191365	**Tabbinet ...**	...Machinery will be shipped by sailing vessel.
191366	**Tabbying ...**	...Your order received and has our best attention.
191367	**Tabebuia ...**	...Remittance follows by mail.
191368	**Tabefatto ...**	...Remittance will be sent immediately for £............
191369	**Tabefied ...**	...Waiting your remittance.
191370	**Tabellaria ...**	...Credit arranged through.
191371	**Tabellaron...**	...Credit arranged by telegraph.
191372	**Tabelle ...**	...£10 additional needed to cover cost.
191373	**Tabelliar ...**	. £20 ,, ,, ,,
191374	**Tabellioa ...**	...£30 ,, ,, ,,
191375	**Tabellions...**	...£40 ,, ,, ,,
191376	**Tabellone ...**	..£50 ,, ,, ,,
191377	**Taberd ...**	...£60 ,, ,, ,,
191378	**Tabergite ...**	...£80 ,, ,, ,,
191379	**Tabernacle**	...£100 ,, ,, ,,
191380	**Tabernero ...**	...£ ,, ,, ,,
191381	**Tabescence**	...We can deliver from stock.
191382	**Tabescent ...**	... ,, ,, in one week.
191383	**Tabetique ...**	... ,, ,, in two weeks.
191384	**Tabicadas ...**	... ,, ,, in three weeks.
191385	**Tabicamos...**	... ,, ,, in four weeks.
191386	**Tibicar ...**	... ,, ,, in six weeks.
191387	**Tabicaron ...**	...The time for delivery should be............weeks.
191388	**Tabicones ...**	.The time of delivery is of great importance.
191389	**Tabido ...**	..All charges will be accounted for............
191390	**Tabificas ...**	...All charges will be paid by............
191391	**Tabiflui ...**	...I (we) cannot promise delivery until............
191392	**Tabifluos ...**	.. I (we) cannot promise delivery in the time stated, letter follows.

Answers, &c.—*Continued.*

191393	**Tabiosis** ...	I (we) cannot promise delivery in time stipulated, please telegraph instructions.
191394	**Tabique** ...	...We have not received yours of the...........
191395	**Tabiqueis** ..	...Replying to your telegram (enquiry), our price is £........ ...
191396	**Tabiquemos**	Replying to your telegram, our price, subject to prompt confirmation of order, will be £..... ......
191397	**Tabiser** ..	...Full information follows by mail.
191398	**Tablaeho** ...	...Tracing and estimate will be sent.
191399	**Tablabo** ...	..Tracing and estimate were sent.
191400	**Tablajero** ...	..We have received your order for...........

GENERAL MESSAGES.

191401	**Tablares** ...	...........steamer is delayed by having to put in at..............
191402	**Tablazones**	...........is erected and works satisfactorily.
191403	**Tablazos** ...	............is erected but does not worked satisfactorily.
191404	**Tableabais**	....is erected but does not yet work satisfactorily, send immediately by quickest route.
191405	**Tableadas**...	....will leave on or about the............
191406	**Tablearia** ...	... . cannot leave before the...........
191407	**Tablearon** ...	...........is completed.
191408	**Tableaux** ...	...I (we) will see you on or about...........
191409	**Tableros** ...	...We must have dimensions, sketches, or drawings.
191410	**Tabliers** ...	...We require more detailed information with reference to............
191411	**Tablilha** ...	...We are sending you additional information with reference to............
191412	**Tablon** ..	...We last heard from you on the...........
191413	**Tabloza** ...	.. Refer to our letter dated... ....
191414	**Taboas** ...	...Refer to our telegram dated............
191415	**Taboinha** ...	..We refer to your letter dated......... ..
191416	**Tabolagem**	...We refer to your telegram dated............
191417	**Taboleiro** ...	...Have you received our order for............
191418	**Taboleta** ...	..We have not received your order for..... ......
191419	**Tabooed** ...	..Please send necessary instructions.
191420	**Taboriten** ...	...Please send confirmation by letter.
191421	**Tabouer** ...	..We forward by steamer advertised to close on the...........
191422	**Tabouret** ...	..Can you forward by the...........
191423	**Tabourine** ...	..The Bill of Lading must be to the order of...........
191424	**Tabraca** ...	...The Bill of Lading must be sent to ....
191425	**Tabrimon** ...	...The Bill of Lading has already been sent to............
191426	**Tabual** ...	..The Bill of Lading has not been received.
191427	**Tabuda** ...	...Delivery cannot be made until we have the Bill of Lading.
191428	**Tabularize**...	..Have you received the Bill of Lading.
191429	**Tabulating**	..Insure to cover cost, freight and insurance.
191430	**Tabulista** ...	...Insure to cover all charges and risks if latter is possible.
191431	**Taburno** ...	...We accept your order for...........
191432	**Tacahout** ...	...We accept your order dated..... ......
191433	**Tacamaca** ...	We cannot accept your order on terms proposed, please refer to our offer.
191434	**Tacca** ...	...Forward as early as possible.
191435	**Tachylite** ..	..We accept your offer dated........ ...
191436	**Tachypetes**	...We can carry out your proposals at extra cost of £...... .....
191437	**Tacitly** ...	...We can carry out your proposals without extra cost.
191438	**Taciturn** ...	...Details of conditions are sent by mail.

DIMENSIONS, &c.

191439	**Tackduty** ..	...The gauge (or span) is..... ......inches.
191440	**Tackled** ...	...The radius is . ...feet.
191441	**Tackling** ..	...The height of lift is...........feet.
191442	**Tacksman** ..	...The speed of lift is...........feet per minute.
191443	**Tackspins** ...	...The maximum load is...........cwts.
191444	**Tactical** ...	...The average load is........ . cwts.
191445	**Tadpoles** ...	..The output per hour is...........
191446	**Taffata** ...	. The effective horse-power is.. ....
191447	**Tacaud** ...	...Of the type referred to in Appleby's Handbook, Section V. page.......

N.B.—The code numbers are for use in case a repetition of the telegram may be necessary.

EXAMPLES OF TELEGRAMS IN THE A1 TELEGRAPHIC CODE.

In order to clearly indicate the Section of this Handbook referred to in Cable correspondence, it has been found convenient to establish a Code word for each volume, and the writer is indebted to a merchant in this country for the subjoined Code words, relating to this series, which are used by himself and his correspondent abroad.

These words accurately define the volume, and the same system is, of course, equally applicable to other sources of information.

Appleby's Handbook of Machinery, Section	I.	**Admugitum**
,, ,, ,, ,,	II.	**Adnatobat**
,, ,, ,, ,,	III.	**Adociria**
,, ,, ,, ,,	IV.	**Adoliridas**
,, ,, ,, ,,	V.	**Adumbrato**
,, ,, ,, ,,	VI., Part A.	**Adonteremo**
,, ,, ,, ,,	VI., Part B.	**Adopertus**

The message consists of one of these words and of those at page 1180 (1888 edition) of the A1 telegraphic Code which—in the sequence in which they are used—indicate respectively (1) the page referred to and (2) the number of line from top of printed matter on that page. Code words for dimensions, weight, &c. will be found at page 1032 to 1052 of that book.

Example.—A correspondent who requires Centrifugal Pumping Machinery with Compound Engine and Boiler to raise 2500 gallons per minute (150,000 gallons per hour), to a height of 27 feet as illustrated and described in Section III, cables: "**Feribile Enrhumer Truchuela Exhalais Trasoneria Trasguaedo Adociria.**"

On reference to the A1 Code the message will be found to read as follows: "Forward immediately by steamer Centrifugal Pump, Compound Engine and Boiler Combined, 150,000 gallons per hour against 27 feet head, page 70, line 23 of Appleby's Handbook of Machinery, Section III."

INDEX.

INTRODUCTORY NOTES

ON THE CONSTRUCTION AND EQUIPMENT OF PUBLIC WORKS.

It is difficult to realize that less than fifty years ago, little, if any, of the machinery referred to in the following pages had been designed or thought of, and that the plant then available for the construction of important Public Works consisted almost exclusively of planks and timber, picks and shovels, blocks and falls, horses, carts, etc. Nevertheless, the work was done by the strong and willing hands then employed, these being organised and directed by the distinguished Architects, Engineers and Builders who have left us so many enduring monuments of their skill and energy.

The use of steam and (more recently) electric power in connection with machinery employed in the construction of railways, docks, large buildings, etc. has undoubtedly been the principal factor in the unparalleled advance made within the above mentioned (comparatively) brief period, and the writer reverts with pleasure to the share it has been his good fortune to have in the production of appliances now almost universally employed, which have very largely contributed to reduce the cost of construction of works and the time occupied in their completion.

The financial effect of these improvements is, that the total cost and the time required for completion being now ascertainable within very narrow limits, the investor is willing to provide capital, at ever decreasing rates of interest, and it may safely be said that the necessary financial support for any commercially sound undertaking can be obtained on very moderate terms.

The following further remarks bearing on this subject are made in the hope that they may be of some service to those whose attention has not hitherto been directed to the arrangement of terms generally acceptable to capitalists.

Financial facilities.—To obtain these on favourable terms it is obviously necessary to afford the fullest possible information with reference to the project, including details which will affect estimates of cost, working expenses and cost of maintenance, and of the assured or probable revenue from traffic and other sources; also details of probable increase in revenue, or in improved value of the property to be affected by the enterprise.

Works commenced on quite a modest scale have, in numberless instances, led to commercial development far surpassing what had been anticipated, and thus we see that land sold at a nominal price, or even freely given, has enhanced the value of the remaining and surrounding property to an extent greatly exceeding the value of the land transferred.

Money subsidies are frequently offered to ensure much needed works being promptly carried out. These sometimes take the form of a lump sum payment, or the subsidy is paid by instalments subject to defined rates of progress being attained. A more usual form, however, is an undertaking—with substantial guarantees—for the payment of interest for a defined period, at a given rate on a given capital.

In the latter cases the terms should be perfectly explicit and unhampered by clauses giving rights to interference which might be exercised to the prejudice of the investor or contractor.

Land grants are a convenient form of subsidy which, in many well-known instances, have afforded the inducement required by financiers to provide capital for the construction and equipment, under the most favourable conditions, of vast works which have eventually become highly remunerative to all concerned.

Security for subsidies is afforded, to some extent, by freedom from charge, or at greatly reduced tariffs, for all services rendered to the grantors of the subsidy. But this is insignificant compared with the indirect advantages which inevitably accrue from enhanced value of landed property, increase in population and employment, and to the general improvement arising from facilities for traffic.

Concessions for water works, gas works, electric lighting installations, tramways, etc are usually negotiable if proper provision is made for exclusive rights extending over an adequate period, also for maximum rates of charge and minimum supply, the interests of the public being safe-guarded by equitable provisions for the fulfilment of the obligations entered into by the Concessionaire.

Sinking fund.—If, as is usual, the concession is granted on condition that the grantors reserve the right to acquire the property at the end of a given period, the terms for the valuation need to be clearly defined, and provision made in the rates charged which will admit of a sinking fund being formed to repay the whole of the capital invested, with or without bonus, at the proposed date for the termination of the concession.

Execution of works.—Whether the undertaking shall be carried out by a contractor responsible for the whole of the work, by departmental contracts, or by the company or corporation which will finally own and manage the property, is purely a matter of convenience.

The first-named arrangement is frequently the most acceptable to Capitalists because—although the Contractor must naturally seek a profit commensurate with the risks involved up to completion—the saving in time and cost, effected by the Contractor's familiarity with methods and appliances, together with the incentive he has, by personal and active supervision, to carry out the work in the quickest and most economical manner, may well be of greater importance than some extra cost to cover his profit.

On the other hand, Works carried out without a Contractor must necessarily be provided with a proper equipment of Machinery, and instances are mentioned further on of judicious initial arrangement whereby a large value of plant used in construction, has been advantageously employed for general service when the works have been completed.

These remarks apply more especially to Docks, Harbours and Water-ways, and to the (by no means exceptional) cases in which the initial outlay must be restricted pending the development of traffic.

Contractors' risks.—It is evidently the duty of Investors to protect their interests by clauses which will ensure proper execution of Contracts. But it is quite another matter to specify conditions which unnecessarily increase the Contractor's risks and so compel him either to largely increase his estimate of cost, or (as has often happened) stipulate terms which neither Capitalist or Contractor are disposed to entertain.

RAILWAYS.—The standard gauge of 4-ft. 8½-ins. (1-m. 435) created by Stephenson and adopted for most of the main lines in Europe, the United States of America, and many other countries, offers much greater facility for obtaining additions to rolling stock and equipments, than any other gauge, and it by no means follows that light railways, for low speeds and light axle loads, must necessarily be narrow gauge lines. In the absence of local conditions unfavourable to a wide gauge, it may—ultimately—be more economical to avoid break of gauge and have both branch (or feeder) and main lines of uniform gauge, the former being a light track sufficient for the loads and speeds passing over it. Perhaps the principal objection to uniformity, is the liability to light and heavy rolling stock and loads being made up in one train.

Break of gauge.—When determining the gauge to be adopted, the extent and nature of traffic, the speeds, gradients, features of the country to be served, the curves and other points need to be carefully considered, preference being given to one of the more largely used gauges with a view of obtaining materials and rolling stock for additions and renewals with some degree of promptness.

A break of gauges becomes of comparatively little importance if sidings, goods sheds, etc. are properly equipped with cranes and other appliances for saving manual labour and time in transferring merchandise from one gauge to the other.

Standards for narrow gauges.—In view of the existing and prospective increase in the use of narrow gauges, it becomes most desirable to standardize the leading dimensions, such as heights of buffers and connections, springs, &c. for each gauge.

Much has been said in favour, respectively, of 2-ft., 2-ft. 6-in., 3-ft. metre and 3-ft. 6-in. gauge, and as is well known, the wider gauges offer undoubted mechanical advantages, but probably the narrow gauges might with advantage be reduced to two, 2-ft. or 2-ft. 6-in. and metre. Whichever of these gauges a concensus of opinion determines as the most useful, there can be no doubt that (as pointed out by Sir W. H. Preece in an address to the members of the Institution of Civil Engineers) standardising dimensions would lead to the usual improvement in quality, reduction in cost of production, and great facility for obtaining supplies.

Narrow gauge lines.—Instances will occur to everyone of the immense value for agricultural, industrial and strategic purposes (as distinct from ordinary main lines) of railways with 2 feet to 3 ft. 6in. gauge "Pioneer" lines, or for permanent service in localities which present structural difficulties, or can neither provide the capital required for the construction and equipment of a heavy line of the normal type, nor the traffic to adequately employ it.

It is evidently desirable to obtain advice from a competent engineer with regard to the contemplated railway and its equipment but, if this is not available, the information given in this volume with reference to the approximate prices of materials and rolling stock, the carrying capacity of vehicles and the hauling power and speed of locomotives on different gradients, will materially aid in estimating the probable cost of track and rolling stock.

The cost of earthworks, bridges and other works of art can, of course only be ascertained after careful examination of the local conditions ; general information on some of these subjects will, however, be found by reference to the respective headings relating to them.

PORTABLE RAILWAYS.—A system of narrow gauge railway, easily and quickly removed and re-laid, is now considered an essential part of the plant used in the construction of docks, railways and other important works, also for transporting minerals, timber, agricultural and other produce for shipment or consumption.

Railways for these purposes of any gauge between 16 and 30 inches (40 to 75 centimetres) are constructed of steel rails, rivetted or bolted to steel sleepers spaced about 2-ft. 6-in. to 2-ft. 9-in. centre to centre and usually put together in lengths of 16-ft. for facility in handling.

How great this facility is, is demonstrated by the fact that 750-ft. of line have been disconnected, relaid at a distance of 150-ft. and re-connected to the main line, by four men in twenty minutes, so that in a few hours a considerable length of line, which has served its purpose in one place, may be removed and relaid ready for work in other places where required.

This subject is referred to in detail under its proper heading, but it may be well here to mention that the gauges best adapted to different working conditions usually are : 16, 18 and 20-in. gauge for light loads and manual power ; 20 to 24-in. for animal haulage ; and for locomotive traction any gauge up to 30-in. which may be regarded as the maximum gauge for light portable railways.

EXCEPTIONAL USE OF PORTABLE RAILWAY.—The following example of service rendered by portable railway, will be worthy of consideration when difficulties in transport have to be overcome.

The work performed consisted of transporting nearly 100 tons of plant and machinery over difficult country, and a distance of about 125 miles.

Plant employed.—Twelve wagons and about 650 yards of track were used, the track over which the train had passed being successively taken up and laid down in front.

Time occupied.—Notwithstanding many serious difficulties, the work was successfully completed in less than three months.

TRAM LINES IN WORKS connected with a main line system are conveniently arranged by laying two light intermediate rails between those forming the 4-ft. 8½-in. gauge. This combination leaves the standard gauge available for main line stock, and provides up and down narrow gauge tracks for bogie trucks, the wheels running on the main line on one side and on the intermediate rail on the other side.

The writer has adopted this system with great advantage, the main line being 4-ft. 8½-in. gauge and the bogie tracks 18-in. gauge.

If there is no connection with a main line 2-ft. 6-in. gauge is perhaps the most convenient, the materials for which can always be promptly supplied.

MACHINERY FOR WORKS IN CONSTRUCTION.—Information with reference to most kinds of machinery used in constructive operations will be found in this and the other volumes of this series, but, as is well known to experts, much depends on judicious selection, and on some technical or financial considerations.

If advice on this subject is desired, as much information as possible should be given, more especially as to :

(*a*) The nature of the work and the time in which it is to be completed.
(*b*) The quality and local value of skilled and ordinary manual labour, and if possible, the cost of earthwork per cubic yard or metre.
(*c*) Whether—and to what extent—the outlay for plant must be restricted.
(*d*) Whether it is desirable that any of the plant should be utilised for ultimate permanent service.

As indicated under the heading "Execution of Works," plant used in construction can frequently be arranged to be just as fit for ulterior use as if it were specially purchased for that purpose. The writer can point to many instances in which this policy has been adopted with most satisfactory results.

The equipment of Docks, Goods Stations, etc. must naturally be arranged with special reference to the existing or prospective traffic, regard being given to that which may be expected to predominate or increase.

In some cases the bulk of the traffic is respectively "export" or "import," whilst in others it is about equally divided. But, as is well known by experienced traffic Managers, the present and prospective conditions must be studied and plant provided for performing the work in the least possible time and with the utmost economy in working expenses, care being taken to afford facilities for extensions, which are invariably required where the existing traffic has been satisfactorily dealt with.

Some examples of Machinery for these purposes will be found in this volume, but the subject is treated with much more detail in Section II. of this series, and that of the arrangement and equipment of Repairing Shops for Docks and Railways in Section IV.

Transmission of power.—Steam power applied directly or indirectly—as in generating hydraulic pressure, compressed air, etc.—has hitherto, for the most part, replaced the animal and manual power formerly employed in constructive operations. But the flexibility, safety and high efficiency of the electric system is causing it to rapidly supersede other modes of transmitting power for lifting, pumping, traction, and many other purposes, examples of which will be found in this volume, and in Sections II., III. and IV.

Steam power as applied to fixed and portable steam cranes, and for driving, pumping, grinding, mixing and other machines, offers the unquestionable advantage of each machine being complete with its own engine, boiler, etc. For this reason steam, as the motive power, must always predominate in works under construction, in quarries, for service on railways, in iron and steel works, and for innumerable purposes where, for convenience and economy, the machinery employed must be equally adapted for concentration or for wide distribution.

STEAM CRANES.—Whether steam cranes shall be used exclusively in docks, railway goods yards, etc. or only in conjunction with a main system of hydraulic or electric machinery, is largely a question of capital outlay. They can be, and often are, provided two or three at a time, to cope with natural growths of traffic, whereas an installation for the distribution of hydraulic power from a central station, must necessarily be on a scale commensurate with probable future demands, and thus involve an outlay which must for some time be, at all events, partially unremunerative.

There is the further advantage that if, or when, a change of system seems to be desirable, the experience gained infallibly indicates the most suitable types and disposition of machines as well as the extent to which they will, in the near future, be profitably employed, the steam cranes are always available for subsidiary work or for service in emergencies.

The writer recalls to mind many instances in which this policy has been adopted with marked economy and success.

HYDRAULIC CRANES.—If a sufficiently large number of cranes, capstans, or other machines will be employed to justify the outlay for a power station with the necessary pumping engines, accumulators, hydraulic mains and machines, the hydraulic system affords such facilities for transmitting power through long distances and with absolute safety, that these and some other considerations are far more important than the loss in useful effect which is incidental to the production of hydraulic pressure by steam power.

The great convenience of having power always available, the noiseless working, simplicity of mechanism and the low cost of maintenance, are elements which greatly favour the use of hydraulic power, but as already indicated, to be fairly economical, a considerable number of machines should be continuously employed. Portable hydraulic cranes can, of course, only be used in proximity with the hydraulic mains, so that a few steam cranes to travel by their own steam power, haul trucks, etc. are almost always required.

ELECTRIC CRANES.—The high efficiency and flexibility of electric transmission of power, regardless of heat or cold, distance or contour of ground, has led to the rapid extension of its application to cranes, pumping and general machinery as well as for traction and other purposes.

The electric current, generated at the Central Station by engines and boilers of the most economical type, is conveyed by overhead or underground conductors in any direction and to any distance with so little loss in pressure that even in installations of moderate power an efficiency of 90 per cent. is attainable at the motor terminals. It follows therefore that this highly convenient and economical mode of transmitting power must be peculiarly adapted for use in connection with cranes or other appliances, whether grouped within a limited area, as in workshops, concrete block making yards, etc. or widely distributed as in docks, and railway goods stations.

Quick working cranes.—Amongst the advantages accruing from the use of quick working cranes may be mentioned the increase in earning power of rolling stock and steamers, due to acceleration in the speed of handling materials and merchandise, with large rednetion in the number of hands employed. Some data with reference to working expenses and number of hands required will be found further on and in Section II. of this series.

Electric installations for small stations.—In view of the extended use of electric lighting and the ever increasing demand for prompt delivery of merchandise, the writer believes that in the near future all large and many comparatively unimportant stations will be equipped with their own installations for lighting and for working cranes, pumps, &c. by electric current, or will be supplied from a central station.

Economical considerations.—Features of primary importance in the electric system are:

(*a*) That although power is instantly available, no fuel or water is wasted when machines are standing, and

(*b*) That the power consumed is limited to that required for the work actually performed.

Thus, if an electric crane of 30-cwt. power is employed in working loads of (say) 10 cwt. there is absolutely no waste of power, whereas with the hydraulic system the full power is exerted however much the load may be below the maximum for which the crane was designed. This going on, as it must do, for hours, and even days consecutively, naturally entails waste of fuel.

Electric traction.—The foregoing remarks lead to the conclusion that for branch line service with the (usually) widely varying loads, frequent stops and occasional long waits, a large economy in fuel will be effected by substituting electric for the ordinary locomotive traction.

HANDLING MINERALS.—Seeing that more than 200,000,000 tons of coal are raised in Great Britain alone, and at least 60,000,000 tons of ore, stone, salt, &c. have to be handled every year, an average saving of only 1 penny per ton on this gigantic total of 260,000,000 tons represents more than £1,000,000, and clearly indicates the importance of even minute savings in the cost of manipulation.

End and side opening trucks.—Attention may be directed to the facilities for discharging afforded by trucks of this type, to carry 8 to 10 tons of coal or proportionate weight of other minerals, which go far towards neutralising the advantages claimed for much larger trucks.

Relative advantages of cranes and tips.—Which system shall be adopted is largely a question of convenience in the arrangement of approaches and sidings. Provided that these conditions are equally favourable for the respective modes of handling, the cost of labour and speed of working are also about equal, and—as already pointed out—facilities for this purpose materially reduce the cost of labour and increase the earning power of the wharves and of the rolling stock.

COALING PONTOONS, constructed of steel or timber—usually the former—of the dimension required for the work to be performed, are moored in smooth water with depth sufficient for the largest steamer to come alongside.

The deck of the pontoon is provided with steam, electric, or hydraulic cranes, which transfer the coal by means of grabs or turnover skips, from the collier to lighters alongside, or into storage hoppers for future distribution, the coal being automatically weighed in the process of transfer.

The most perfect installations of this type are, unquestionably, those on the Thames, some of which handle as much as 25,000 tons of coal per week, and frequently discharge a 1,500 tons collier in one tide.

The cost of working by Grab is very low, frequently less than one penny per ton and—as pointed out at pages 93 and 94 of Section II. of this series—the loss by breakage is far less than that incidental to unloading coal in any other way.

DISCHARGING COAL BY CRANE AND GRAB.—Coal brought alongside by water has been discharged by Crane and Grab, delivered into trucks and trammed to conveniently arranged Hoppers or to the Retort house, at a total average cost of twopence per ton. Plant for this purpose is illustrated at pages 64 and 65.

The items of cost are: Filling and trimming grab, per ton, 0·75 pence; crane driver, 0·50 pence; truck men, 0·75 pence; total 2 pence per ton.

DISCHARGING COAL BY CRANE AND TURN-OVER SKIPS and tramming into store as above costs 4¾ pence per ton.

The items of cost are: Filling skip, per ton, 3 pence; tipper, 0·50 pence; crane driver, 0·50 pence; truck men, 0·75 pence; total 4¾ pence per ton.

Discharging from barge and loading into trucks.—The Crane, Grab and Coal for working being found by the Company, the driver does the work at rates of 1d. per ton for Coal and 2½d. for Coke, he providing all the labour for filling and final trimming.

RELATIVE ECONOMY OF THE TWO SYSTEMS.—It has been pointed out by Mr. Carpenter, M. Inst. C.E., that a saving of 1d. per ton on the 3,250,000 tons of coal carbonised in London alone, is equal to about £13,500 per annum, or more than £54,000 per annum on the 13,000,000 tons used annually for gas making in the United Kingdom.

From these figures it will be seen that a saving of 2¾d. per ton on each 10,000 tons handled is equivalent to nearly £115 per annum; but this is by no means the full extent of direct saving effected by the use of Crane and Grab, it has been as much as 4d. per ton, in addition to that due to the quicker despatch of the coaling craft.

COALING CRANES AND DERRICKS.—A few of the appliances which are principally employed in loading and discharging Coal and Minerals are referred to in this volume and in Section II., but many installations designed to fulfil special conditions must remain unnoticed.

The advantages of Cranes of the type illustrated by Figs. 5040 and 5044 are that they are complete in themselves, and—although constructed to afford the best facilities for the above named work—they are equally good for general service.

The last remark does not apply to Coaling Derricks, but it is sometimes necessary to use them where the load must always be discharged at one point and there are objections to the jib swinging over a large area.

COAL TIP.—As indicated in Fig. 5043, this consists of a rectangular tower with table to carry a truck with opening end and raise it to the height required. The tower is fixed as near as possible to the edge of the Quay, and is provided with projecting shoots, adjustable vertically to the angle suitable for the height of ships decks above water level and the different kinds of coal handled. When the truck has been raised to the proper height, the end door is opened and, at the same moment, the back end is automatically tilted into the position most favourable for discharging the coal over the shoots into the ship's hold.

The lifting and other motions are performed by Hydraulic, Steam or Electric Power (usually Hydraulic) and the cost of working and of maintenance are both remarkably low. It will be evident that coal and mineral tips must be specially designed to suit the size and weight of trucks, height of lift and other constantly varying conditions, also that they can be used for only one class of work.

ELEVATORS AND TRANSPORTERS.—Many improvements have recently been made in fixed and portable machinery for lifting and distributing coal, minerals, grain and other materials handled by skips.

Some information will be found in the following pages under the above headings, but appliances for these purposes need to be designed to perform their work at maximum speed and minimum cost, so that the engravings and descriptions can do little more than serve as indications of the kind of mechanism employed and the data required for devising what is required for the work contemplated.

Grain elevators and distributors.—The machinery employed for raising grain by bucket elevators and carrying it any distance by endless band for distribution where desired, is so largely used in this country and on the American Continent, that it is too well known to need detailed description, but as this remark scarcely applies to the pneumatic system, reference to it will be found under its proper heading.

The grain is cleansed and aerated, to some extent, by both systems, but much more completely by the pneumatic than by the bucket and endless band elevators.

Pneumatic Grain Elevators.—Amongst the advantages claimed for this mode of lifting and distributing grain may be mentioned: (1) The improvement in the grain effected by intimate contact with the conveying air; (2) The facility for reaching any part of the hold and for delivering overside or to any part of the grain stores without hand labour; (3) The entire absence of risk of accidents to workmen, and (4) the low cost of working, frequently less than the wages paid for trimming.

DISCHARGING GRAIN BY CRANES.—If the grain traffic is not sufficiently important to justify the rather considerable outlay for stores and elevators, much may be gained by using grabs of the type Fig. 5114, in connection with the steam or other quick working cranes of two or three tons power with which most water-side premises are equipped.

The grabs open automatically and if they are arranged to discharge into a fixed or portable hopper, the grain or seed is weighed and sacked without manual labour.

The working expenses are usually about 1d. to 1½d. per ton of grain handled.

STEAM EXCAVATOR or "NAVVY."—So far as dock, water-way and railway construction is concerned, and for getting clay, chalk, ores and similar materials, a steam crane excavator of the type illustrated by Fig. 5105 is generally the most useful, because it can swing and deposit its load at any point in the circle described by the jib; this sometimes saves excavating a width of gullet only required for the approach of trucks, on one or both sides of the machine, to carry away the material excavated, but obviously, it will not excavate below the crane carriage, a second stage being required for this.

Sideway excavators.—The work is performed by ladder and buckets, which excavate to a considerable depth below the rails on which the machine travels. The machinery is generally similar to that used for sub-aqueous dredging.

EXCAVATION BY GRAB.—This system is available where no other mechanical digger can be used, but in hard ground, or for a long run of excavation, it does not compare favourably with the machines above named either in regard to quantity or cost of work performed.

DREDGERS AND SUB-AQUEOUS EXCAVATORS.—Although the familiar ladder and bucket dredger is absolutely indispensable for a large proportion of the work to be done, the much less costly suction dredger, or the grab or dipper, render valuable service under some of the conditions mentioned further on.

A few examples are given of each system, together with indications of the details required for the preparation of designs and estimates.

PILE DRIVERS.—The selection of plant for this purpose (illustrated and described at pages 42 to 49) is influenced mainly by the extent of the work to be performed in a given time, the nature of the ground and of the structures—existing or to be erected—for carrying the pile-driving machines. These considerations also involve questions relating to concentration or distribution of weight of parts, continuity of work, facilities for removal, etc.

As a rule, the work is done much more rapidly and at far less cost by steam or electric power than by manual labour, but it has been found, exceptionally, that owing to the time consumed in taking down, transporting, and refixing machinery, the balance of advantage is in favour of hand power.

BORING TOOLS AND ROCK DRILLS.—These subjects are treated in Sections 3 and 6, but these tools being indispensable in many undertakings, they must necessarily be referred to in this volume.

Well boring tools for determining the characteristics of ground to carry foundations and the depth to which they shall be carried, as well as for well-sinking, putting down bore-holes, etc. are usually of the ordinary type.

The diamond drill, patented by the writer and first built by his firm, is invaluable for putting down the deep bores required for Artesian water supply, prospecting for minerals, etc. and is the only machine which provides accurate records of all the strata passed through from the surface to the botton of the bore. Some examples of these machines are given further on with estimates of approximate cost.

Percussive rock drills for quarries and open cutting, sinking shafts, driving headings, etc. to work with steam, compressed air, or manual power are also referred to in the following pages.

CONCRETE MIXING MACHINERY may be classified under the terms "continuous delivery" and "intermittent delivery." The quality of the concrete produced by either system is equally good, but—relatively with the cost of the machine—the output under the continuous system is rather greater than that obtained from machines with intermittent delivery, and the cost of labour is less.

Intermittent delivery machines are, however, invaluable where it is more convenient to move the machine to the point where the concrete has to be deposited in blocks, in monolith, or for filling in.

CONCRETE BLOCK LIFTING MACHINERY.—This subject is treated at some length in Section II. of this series, and further examples of plant recently constructed will be found at pages 16 to 26.

As pointed out elsewhere, no two installations are sufficiently alike for engravings to be of much service, excepting as indications of machinery which has been successfully employed under one set of conditions, and so aid in the arrangement of plant suitable for those to be fulfilled.

CONTRACTORS' PLANT AND MATERIALS.—Those only who have been engaged in arranging the plant to be provided for use in the construction of works—ever varying in complexity and magnitude—can adequately appreciate the wide range of materials which must be at hand when required to ensure the economy now universally sought, and the despatch with which they must be completed.

It is difficult enough, even in this country, where supplies of all kinds are easily obtained, to have at hand all the materials and appliances suddenly required for unforeseen contingencies. How much more difficult then is it, to provide for such contingencies in localities, where (as in the writer's experience) there were no local supplies and where even a gross of shovels or a ton of good chain could not be obtained in less than 4 to 6 weeks.

Evidently the only course, under such circumstances, is to provide amply for all probable wants, and the rather diffuse list of articles under this heading is intended to furnish facilities for so doing. Some of them may seem trivial, but their importance is fully established when they are wanted and cannot be had.

CONTRACTORS' MACHINERY.—Most of the types of contractors machinery, in general use, are referred to in this volume, or in others of this series, but many modifications have been made, and plant specially designed for exceptional service, which must remain unnoticed.

Maintenance.—That contractors machinery is less carefully handled than that in workshops or factories is inevitable, and the importance of keeping it in the best possible condition is self-evident.

In the absence of works where minor repairs can be done locally at reasonable cost, and in reasonable time, a small repairing shop, with a modest equipment of tools, has always proved to be an excellent investment on works of even moderate extent; in some of the cases which will be mentioned it has been quite indispensable.

Inspection.—Great advantage has also been derived from the appointment of a trustworthy mechanical engineer, whose duty it is to examine the plant and arrange for all necessary repairs, without waiting for notification from the man in charge of the machine that repairs are needed; for various reasons such notification may not be given.

Both of the last named arrangements have frequently been adopted on the writer's suggestion, always with the best results.

That one or more men are profitably employed in maintaining plant in full efficiency was demonstrated during the construction of the Thames Embankment, where a large quantity of plant designed and built by the writer was employed—for the most part day and night—in a very restricted area.

More recently, nearly 100 Steam Cranes of the type Fig. 5037, with corresponding quantities of plant of other kinds, were employed in the construction of one Dock in this country.

PLANT FOR HARBOUR AND RAILWAY CONSTRUCTION.—Another undertaking, differing widely from those last mentioned and referred to in detail at pages 10 to 27, consists of Harbour Works, Docks, Quarries, and Railway extensions, and was carried out by a foreign Government, the whole of the plant being supplied by the writer, or under his advice.

In this case, the Cranes, Repairing Shops, and certain portions of the Machinery employed during construction (which occupied about 5 years) have been retained for permanent service and are still so employed after nearly 20 years constant use.

The Manchester Ship Canal.—Numerous other examples could be given of plant provided for works of all kinds in this and other countries, but the remarks on this subject may fitly conclude with a record of the principal items comprised in the plant provided for the construction of this gigantic undertaking.

There were 170 locomotives, 6,000 wagons, and more than 200 miles of contractors' temporary railway; 100 steam navvys and 10 powerful dredgers were required for excavation. There were 200 pumps of various kinds, 180 fixed and portable engines, and 60 pile-driving machines with central and subsidiary stores and repairing shops for proper maintenance.

The excavations consisted of about 41,000,000 cubic yards of soil and 10,000,000 cubic yards of sandstone rock, or 51,000,000 cubic yards in all (= about 76,000,000 tons).

Bricks and concrete.—The brickworks attached to the canal works supplied 450,000 bricks per month, and about 8,000 tons of concrete, in various forms, was used per month. The average monthly consumption of coal was 10,000 tons.

The number of hands employed varied between 10,000 and 16,000.

REMUNERATIVE OUTLAY FOR PLANT.—It is stated by Sir J. Wolfe Barry that the estimate for plant for large works of construction is usually 8 to 10 per cent. of the total contract sum.

This, however, varies widely according to the cost of ordinary and skilled labour, the time in which the work is to be completed and many other conditions.

Ultimate cost.—It may be well to direct attention to the fact that the actual ultimate cost of plant (assuming it to be sold or taken away as an asset when the works have been completed) is usually very much reduced if care is taken in selecting it if possible with a view to future general utility, and having it made by firms of good standing and reputation. These points will probably be found to be of far greater importance than relatively small savings in first cost.

SEQUENCE OF RAILWAY CONSTRUCTION.—Great as is the diversity in procedure in the construction of railways, the sequence in which the work is attacked will be very generally as follows for lines to be constructed quickly and economically.

Commencing with the point, or points, where the rails and other materials are most conveniently delivered, the ground is cleared of timber or other obstructions and earthworks commenced, the platelayers following to put down a road for temporary service ; temporary bridges for gaps left for bridges, culverts, etc. can frequently be carried on crib abutments, for which probably sleepers may be used.

Where heavy cuttings or banks occur, diversions may be necessary and (these being merely for temporary service) the question of grade need not be too closely considered.

The permanent way gangs—following the above-named—finish the work, including works of art, permanent bridges, etc.

In districts where streams are insignificant for the greater part of the year, but become, at times, torrents inundating large tracts of country, it will often be found cheaper to put in substantial bridges than incur the risk of a wash-out.

If complete surveys have not been made, the number of girders of standard spans (such as 12, 14, 16, 20, 30, or up to 70 feet, see page 214) needed for 5 to 10 miles can usually be estimated with sufficient accuracy to justify a certain number of them being sent out ready for putting in place and so save considerable delay, and perhaps money, in structures which eventually are useless.

To these may be added a certain number (also easily estimated) of screw piles or cylinders of standard lengths to form piers or abutments and further important savings in time effected.

Mention is made elsewhere (see page 203) of the convenience and economy of standard types and spans of bridges, roofs, etc. which can be produced at minimum cost and will be easily duplicated.

DREDGING & HARBOUR CONSTRUCTION.

The writer is indebted to a former pupil for the following interesting notes relating to work recently carried out under his supervision, which are the more valuable inasmuch as they afford reliable data relating to the conditions under which each of the three systems of dredging referred to in the previous pages, have been successfully employed. The work consists of:

The formation of two moles to protect the entrance. The respective lengths are 3450-ft. and 2040-ft. the height is 12-ft. above the level of highest tide, with wharfage accommodation on each mole.

Subaqueous excavation of coralline limestone, which formed a bar across the estuary. This has been removed by dredging over a width of 450-ft. and the present depth at low water is 30-ft.

Dredging inner basin.—An inner basin has been dredged to a depth of 30-ft. below low water; the length is 3950-ft. and the width 1200-ft. with quays, and railway on each side connecting them with the main line.

Jetties.—Seven jetties have been constructed, each about 400-ft. long, and arranged obliquely with the line of quay, with berthage on both sides.

Reclamation of land.—About 85 acres of land were reclaimed by delivering the spoil from the inner basin, on low-lying land to provide space for sidings, warehouses and—eventually —for a graving dock, slip-way, and some subsidiary works.

The moles are constructed in "pierres perdues" of the necessary width and batter, the height above highest tide being 12 feet. The stone was brought to each mole by rail, and the total quantity used was about 575,600 cubic yards.

The average cost of the work was 3/6½ per cubic yard.

Subaqueous excavation.—The rock was shattered by explosives and removed by specially constructed ladder and bucket dredgers, and—to ensure uniform results—careful preliminary experiments were made to determine the size of holes, the distance between them, and the kind of explosive which would reduce the disintegrated rock to sizes sufficiently uniform to be easily dealt with by the dredger.

The holes were then put down, by manual labour, from portable stages with a simple form of gauge for regulating the distance between holes, and obtaining the desired result in the sizes of rock to be dredged.

About 540,000 cubic yards of rock were removed in this manner in less than 2½ years, and no difficulties of any kind were experienced.

The average cost of these operations, including explosives and removal of the spoil, was 4/1 per cubic yard.

The inner basin was dredged by a suction dredger (of the type referred to at page 153), and delivered as much of the spoil as was required direct on to the site to be reclaimed, the rest being carried out to sea.

The total quantity removed was about 1,260,000 cubic yards, and the average cost, including discharging in deep water outside, was less than 6½d. per cubic yard.

Dipper (or Grab) Dredgers were used for removing blasted rock, and for clearing away weeds and other obstructions which greatly impeded the operations of the other dredgers.

No record was kept of the quantities removed, or of working expenses, but as the latter are limited to the wages of one man and a few cwts. of coal per day, the total cost is very small.

The total length of wharfage provided by these works is about 12,500 feet, with complete and ample railway accommodation in main line and in the sidings on, both sides of the basin.

The foregoing costs include all supervision, labour, and cost of repairs and renewals, with the high rates of Colonial wages, but they do not include interest on capital, or charges for use of plant.

The miscellaneous plant employed consisted of steam pile drivers of the type Fig. 5021, which are easily removed and require only a light staging, steam being supplied from boilers afloat; the water jet, referred to at page 48, was used to accelerate the speed of driving. A pile cutting machine dressed the heads to a uniform height, and there was the usual equipment of locomotives and trucks, concrete mixers, mortar mills, etc.

Repairing shop.—This was provided with the plant and machinery strictly necessary for the prompt execution of work requisite for proper maintenance of the plant, and for obtaining an accurate record of all outlay for that purpose.

ROCK CUTTING RAMS reduce the hardest rock to dredgable size by the impact of an iron bar with hardened steel point, without the aid of explosives which is frequently inadmissible.

Floating rock cutting rams carried on a barge or raft are efficient to any depth required for navigation, and in all states of tide.

The plant and machinery consist of a steel pointed wrought iron ram weighing from 2 to 8 or 10 tons, according to the nature of the rock and the size to which it is to be reduced. The appliances for working the ram are a pair of strong timber guides and a hoisting engine of the power required to give 40 or 60 blows of the ram per hour; also the winches, fair-leads, etc. necessary for adjusting the position of the barge.

For use on shore in the formation of cuttings, excavation of rock foundations and similar work, the machinery—as above described—is mounted on a strong timber under-carriage for facility of removal to fresh ground.

Work performed.—One of these rams, mounted on a barge, has broken up for removal by dredger, or by crane and grab, 4 cubic yards of rock per hour at varying depths up to 40 feet below water level, and deepened the channel to that extent; this result is, of course, doubled if two rams are used.

Working expenses.—The consumption of fuel is about 1 ton of coal per day (10 hours) for a single cutter, or 1½ tons for double cutters, and quite a small staff is required to work the plant.

Information required.—This is principally: The nature of the rock to be operated on. The quantity to be removed in a given time. Whether the work is subaqueous or on land, and (in the former case) all necessary limits as to draught, depth of working, etc.

PLANT FOR CONSTRUCTING BREAKWATERS IN RANDOM WORK (pierre perdues).—Concrete mixing machinery, cranes and other plant for making and manipulating concrete blocks being referred to elsewhere, it will only be necessary here to illustrate and describe plant which has been successfully used for transporting and depositing materials for the formation of extensive breakwater works in open sea.

These records of work, with which the writer has been closely connected, will also serve as a general indication of the kind of plant required for similar undertakings, although differing widely in proportions and disposition from those now described.

FORMATION OF BREAKWATER.—A rubble bed about 8 feet thick was put down, and levelled to form a foundation for the concrete blocks—each weighing about 30 tons—to be deposited on it. The next operation was to lay a course of blocks, more or less symmetrically, which constitute a kind of boundary wall on each side of the space (84 feet) assigned for the maximum base width of the random work.

DIMENSIONS OF BREAKWATER.—The total length is about 3½ miles. The rubble bed, about 8 feet thick, is about 140 feet wide at the base, tapering about 1 in 2, to 112 feet at the top. The cross section of the blocks deposited on this bed is about 84 feet at the base, the maximum height above the rubble bed is 27 feet and the width at the top about 30 feet.

Plant employed.—The rubble was carried to the site of the breakwater in drop-bottom barges of the usual well-known type and deposited in the ordinary manner

The special plant comprised:

- Buoys, chains, etc. to which the barges were moored to ensure true alignment of rubble bed and blocks.
- Steam trawling gear for levelling the rubble bed.
- Overhead steam travelling crane for shipping the blocks which are brought to the crane on platform trucks hauled by ordinary locomotives.
- Drop-bottom barges for conveying and depositing the boundary wall blocks (see Fig. 5000).
- Slip-barges for launching the random work blocks up to high water level as represented by Fig. 5001.
- Floating steam crane for depositing blocks above water level as illustrated in Fig. 5003.
- The dredgers used were principally of the type illustrated by Fig. 5106.

Fig. 5000.

An overhead steam travelling crane lifts the 30-tons blocks off the platform trucks and deposits them in the drop bottom barge as illustrated by Fig. 5000, or on slip-barge as required. The crane has quick travelling motion, but like many others specially built for similar purposes, there is no cross traverse motion.

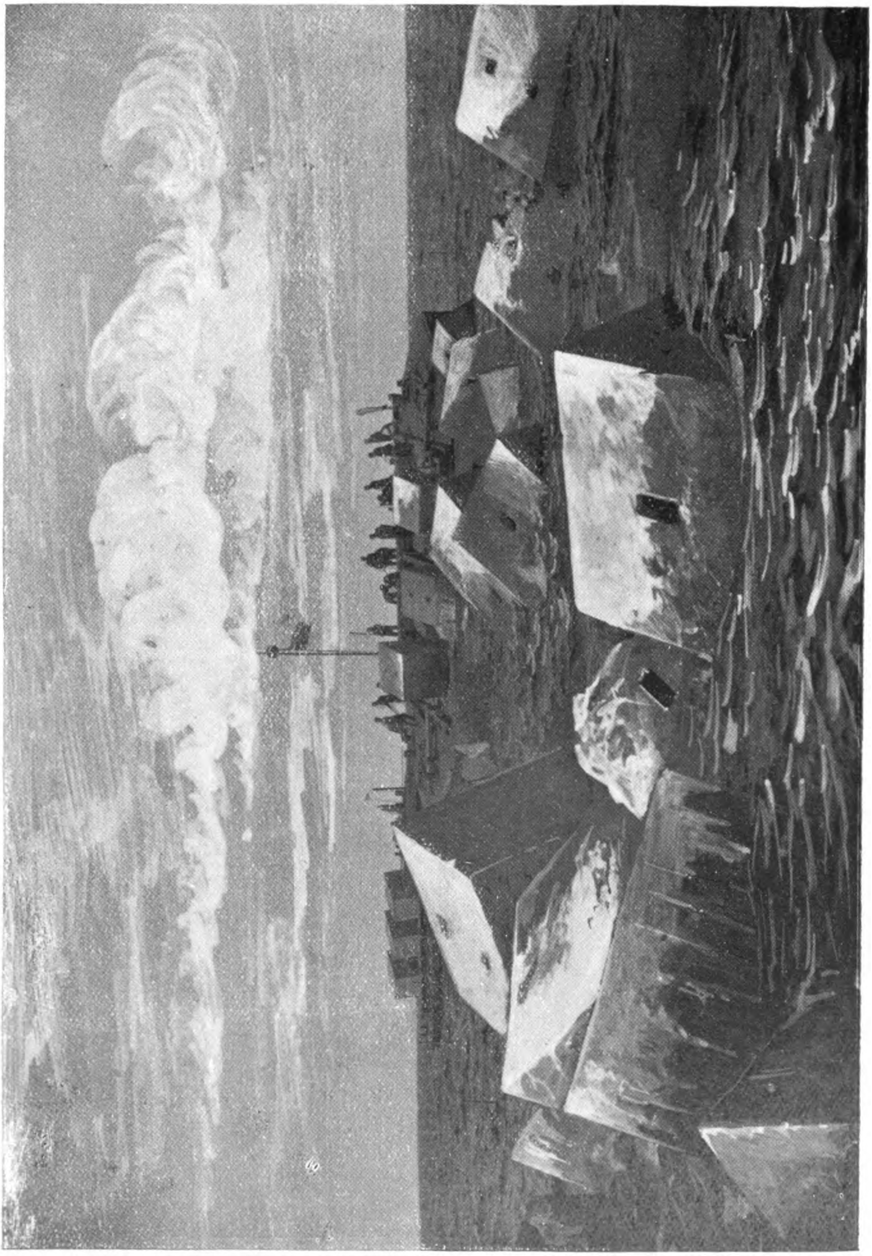


Fig. 5001.

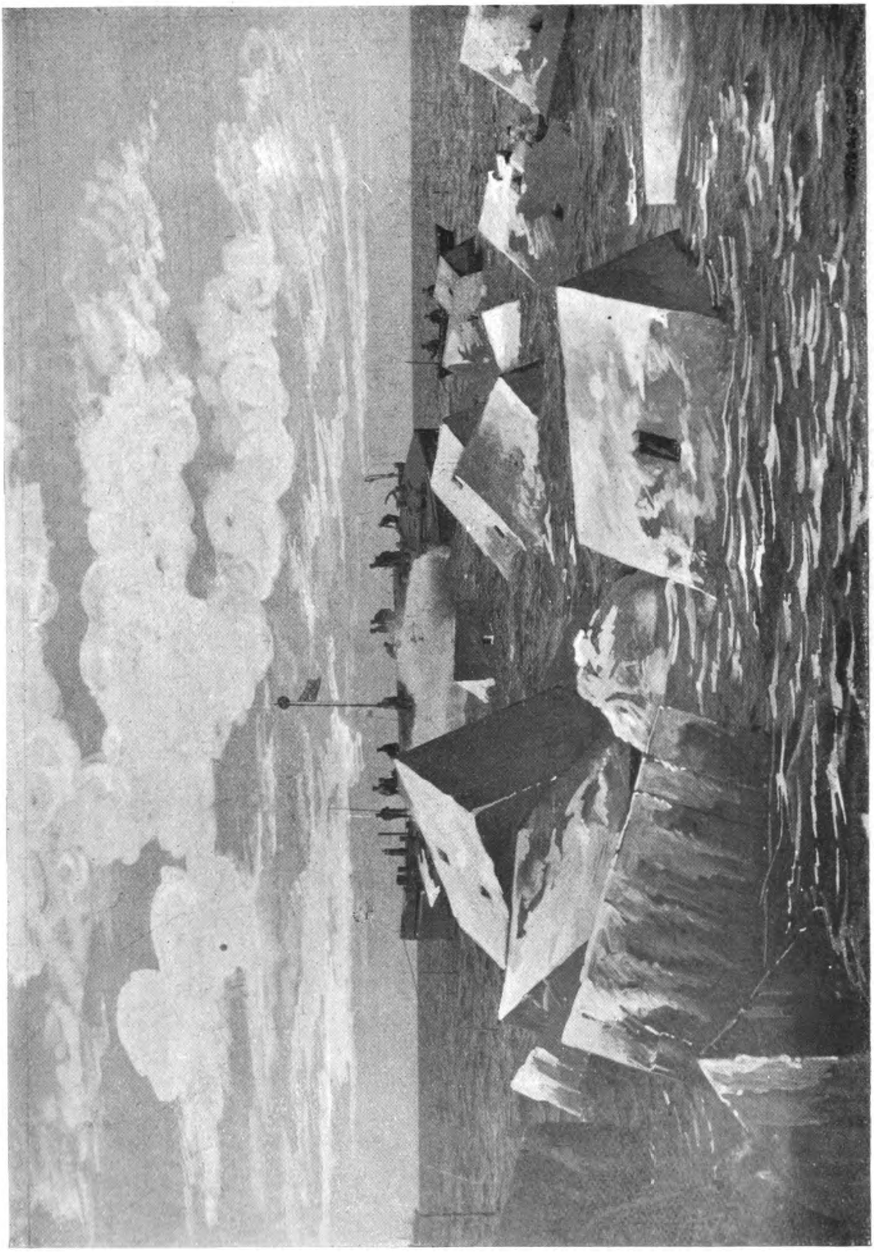


Fig. 5002.

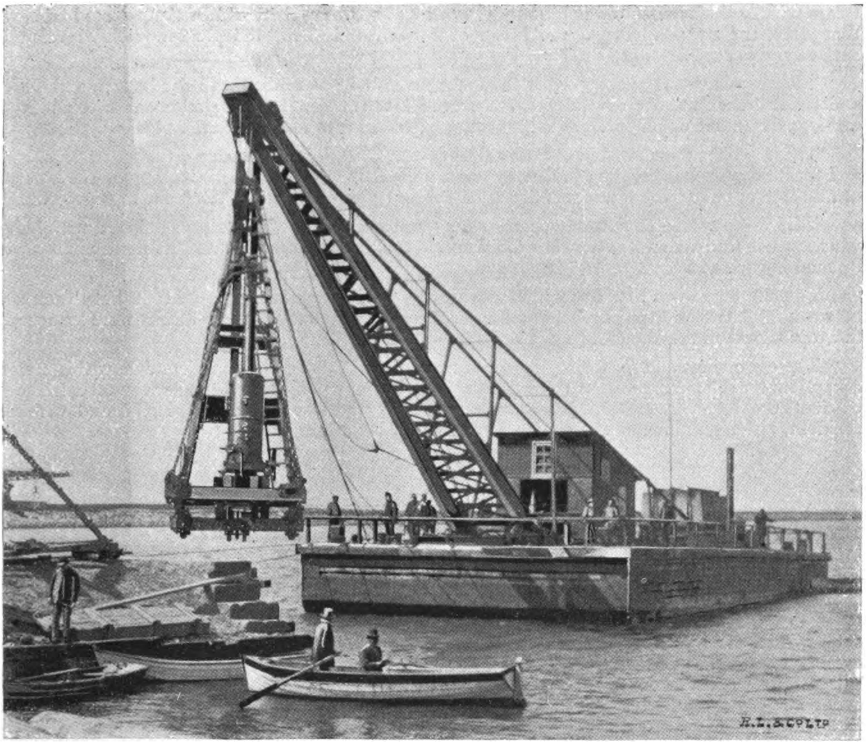


Fig. 5003.

A floating steam crane of 45 tons power, as illustrated by Fig. 5003, with trigger sling gear, was employed for depositing the blocks when the depth of water was insufficient for the slip barges ; these were, however, used to very nearly high-water level.

The drop-bottom barges built in timber to carry five blocks as above indicated were constructed locally, ready to receive the trip and other gear for carrying and dropping the blocks.

Each barge was towed into position over the bed and when moored to the buoys in line to form the wall, all five blocks were usually dropped simultaneously, but the trip gear was arranged to drop any one or more blocks as desired.

Buoys of the usual type were put down at intervals, and at a distance from the centre line of breakwater suitable for both the rubble and block barges to be moored to them, for the purpose of maintaining a true line for the work.

The steam trawling gear consisted of a timber barge about 70-feet long and 20-feet beam, provided with a steam boiler, steam winch and towing frame at the forward end, a short timber jib projecting beyond and above deck level being fixed at the after end.

Two chains from the steam winch are led over pulley blocks, suspended from the jib and carry the trawl box.

The trawl box is constructed of timber, strengthened by angle irons, the bottom being plough shaped and shod with rails and angle irons. This box, filled with stone or concrete to the extent required and suspended by the lifting chains, is held in position by a pair of strong iron bars pivotted at their lower ends to the trawl box, the upper ends working freely on pins with bearings and sole plate secured to a beam extending beyond the sides of the barge, and fixed somewhat forward of midships.

Regulating gear.—The height of the trawl box is adjusted by means of the above-named steam winch, chains, &c. and is held to its work by its own weight and by the pivotted bars, so that when the steam tug tows the barge over the rubble bed, the plough quickly levels the surface and consolidates the mass.

The slip-barges for carrying three blocks, were built of timber with flat bottom and deck, and provided with two cross timbers under each block, tapered to a suitable angle to admit of self-launching, the upper surfaces being well greased prior to loading up the blocks.

These blocks were held in position during transport by strong cams, timber wedges, etc. and the trip gear for releasing the cams was arranged to admit of launching any of the blocks, or all three at once ; the latter was the usual course as will be seen by reference to Fig. 5002.

Winch-barge.—To ensure true alignment and rapid working, a barge equipped with hand winches, fair leads, chains, etc. was placed across the line of formation and its position adjusted by mooring to the buoys.

The slip-barge was then brought alongside the winch-barge and attached to it, but the chains between the latter and the slip-barge were slackened, at the moment the blocks were launched, to avoid shock on the buoys from the re-bound of the slip-barge.

The engravings and foregoing descriptions will probably suffice to indicate how this rather exceptional work was performed, and it only remains to say that the plant was extremely efficient, the breakwater having been completed very rapidly and economically, and without accident, although much of the work was carried on night and day.

TITANS AND BLOCK SETTING PLANT.

Dock and harbour works vary so widely in structural arrangements, proportions and local details, that the machinery employed in their construction must necessarily be designed with special reference to these features, but (with some modification in dimensions, lifting power, etc.) Titan and Goliath cranes similar to those now illustrated have so often been employed that they may be regarded almost as standard types and suitable for most of the conditions ordinarily met with.

Several modes of construction have been adopted, but the steel girder and steel lattice work are unrivalled in rigidity, safety and absence of inconvenience from wind pressure, as well as in cost of construction and of maintenance.

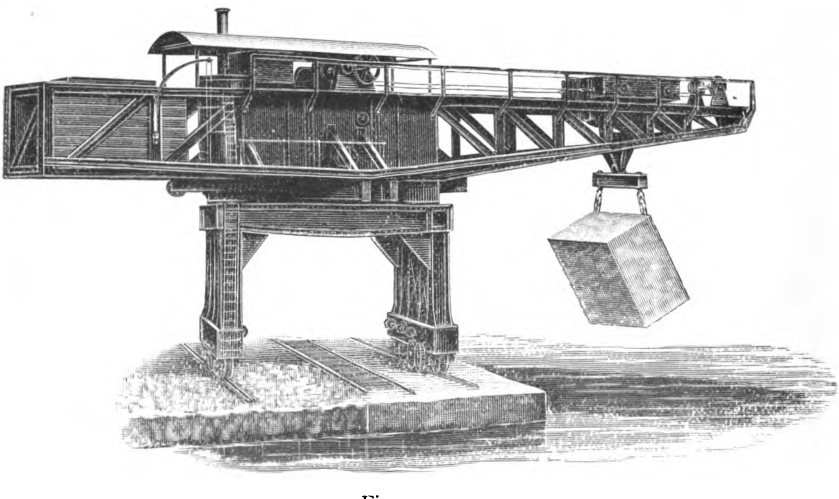


Fig. 5004.

TITAN CRANE OF 55 TONS POWER.—This crane forms a portion of the plant referred to at page 39, which was designed and built by Jessop and Appleby Bros. Ltd. for service in the construction of extensive commercial harbour works and quays carried out by one of the Continental Powers.

Other cranes, differing from this in lifting power and dimensions have been built, but the principles of construction, as illustrated and now described, apply equally to them.

The blocks are lifted by a Goliath crane similar to Fig. 500S, and placed on the truck which conveys them to the Titan.

Lifting and traversing.—The maximum load of 55 tons is lifted at a speed of 1 metre per minute, or light loads at 6 metres (about 20 feet) per minute ; the speed of traverse along the jib is 12 metres (39 feet 4 inches) per minute.

The radius of the jib is 13 metres (about 42 feet 8 inches) and this, with the motions for traversing, suffices for laying the footing blocks and for reaching all parts of the face of the mole.

The titan usually lifts the block from the truck arriving by a track parallel with the line of quay, but the height and width of the travelling gantry admit of the locomotive and loaded truck passing to the other side of the crane, a second line (not shown in the engraving) and cross-over track being provided for returning empty trucks to the yard if the arrival line is blocked.

The jib (of 13 metres radius) rotates around a massive steel post fixed in the centre of the under-carriage platform, and is carried on cast steel conical anti-friction rollers ; these bear on a forged steel path, turned to the same angle as the rollers, which is secured to the lower member of the jib girders.

The gear for turning is provided with friction clutches so arranged that the jib is moved to the right or left, irrespective of the direction of engine stroke, and without resort to the link reversing gear.

Concrete blocks at the after end counterbalance the overhanging jib and part of the weight of the block.

Machinery.—The engines, boiler and machinery for working the motions for lifting and traversing the load, slewing in either direction, and for travelling the crane, with the levers for working these motions separately or in combination, are fixed about centrally and protected by a galvanised iron canopy.

Flexible steel wire rope is used for lifting the load and for traversing the jenney. The rope sheave block has a live ring of steel rollers working against turned steel faces, and the position of the largest block is quite easily adjusted by hand above or below water. The lifting beam is of forged steel and is attached to the lifting block by loop and steel pin.

The gantry or under-carriage is mounted on flanged wheels for a double line on each side ; these, and the gear for travelling, are carried in strong box girders with feet at each end, which are set down to relieve the rails of weight when the crane is block setting.

The cost of Titan cranes of the type referred to, naturally varies in proportion with the dimensions, lifting power, etc. but, if there are no exceptional features, the capital outlay will probably be about as follows :

20 tons	lifting power,	£3,000.	Weight of machinery	about	85 tons.
30 tons	,,	£4,000.	,,	,,	120 tons.
45 tons	,,	£5,500.	,,	,,	180 tons.

ELECTRIC TITANS.—The cranes referred to in the foregoing and following pages are quite easily arranged to be worked by electric current of almost any voltage, and, under most circumstances, this system is very advantageously employed.

TITAN WITH CANTILEVER ARM.—The engraving Fig. 5005 represents a crane, designed and built by the writer's firm, for handling blocks under conditions which involved entire deviation from the usual construction just described.

Conditions to be fulfilled.—In the first instance the crane must lift and lay blocks weighing 60 tons at any point up to 12 metres (39-ft. 4in.) beyond the front of the carriage as well as through a range of 27 metres (98-ft. 6-in.) across the face of the mole, and propel itself back for shelter and forward to follow the work.

Subsequently, the formation width was reduced to 11 metres (about 36-ft.) and provision was made for converting the crane to suit this dimension.

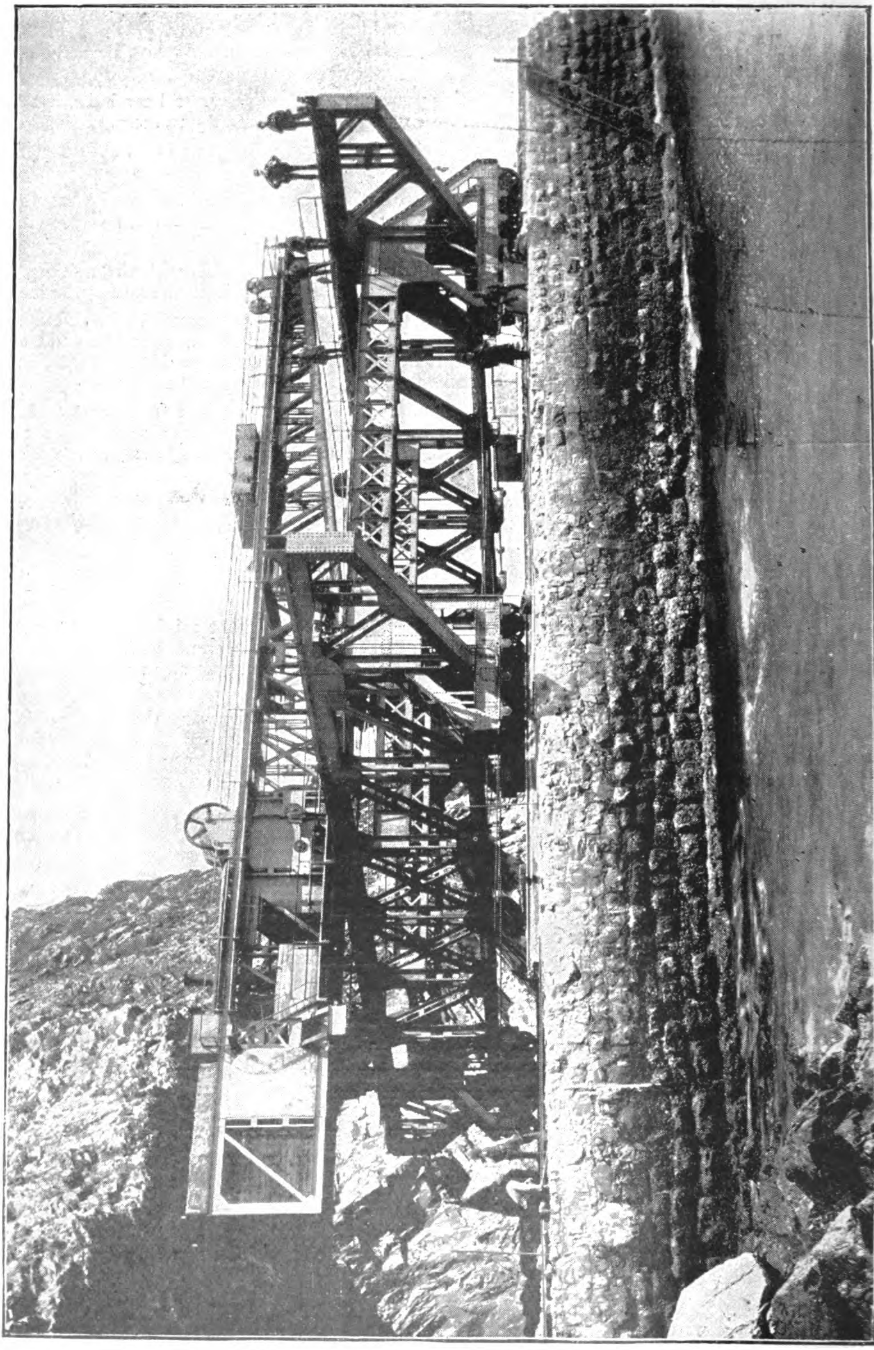


Fig. 5005.

Water transport.—The blocks and all materials used in the formation of the mole were conveyed by water from the blockyard, the plant for which is referred to at pages 37 to 39. Under these circumstances nothing would be gained by having a rotating jib, and as this would be more expensive and would involve difficulties in the ultimate conversion for narrower gauge of crane track, the non-revolving type was adopted. This novel arrangement has proved to be completely successful.

Structure of Titan.—The carriage and traversing arm are built of mild steel, the latter carries the engines, boiler and machinery for transmitting power for lifting, cross traversing and jenneying, and for travelling the crane back and forth. Concrete blocks at the back end of the traversing arm counterbalance the overhanging weight and the load.

Levers for motions and electric signals are conveniently arranged in the engine room and controlled by one man.

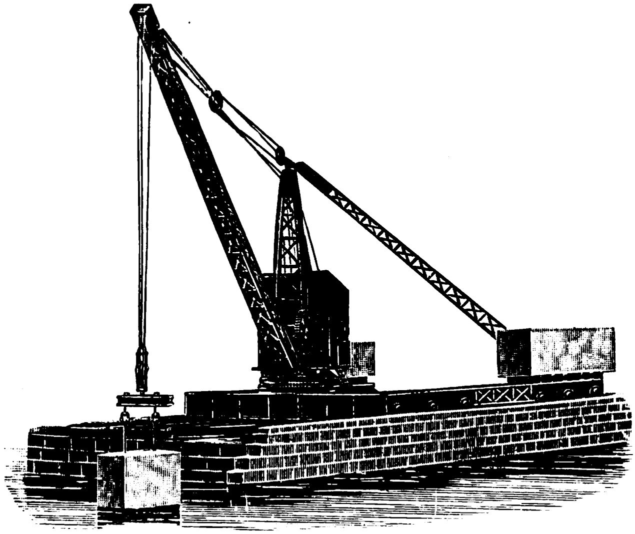


Fig. 5006.

PORTABLE DERRICK BLOCK-SETTING CRANE.—The modification of the well-known and extremely useful safety derrick crane illustrated by Fig. 5006, adapts it for the under-named peculiar conditions, but provision is made for eventually converting it for ordinary service when the mole is completed.

Work to be performed.—The mole, 60 feet wide, is formed of two longitudinal walls, of concrete blocks weighing 30 tons, with cross walls at intervals, the spaces between these being filled in with rubble as the bays are completed.

Machinery employed.—A derrick crane with latticed steel mast, jib, back ties and all appliances for lifting, slewing, altering radius of jib and travelling by steam power, is mounted on a steel girder under-carriage with flanged wheels, which travel on two heavy steel rails laid on each of the longitudinal walls. The necessary stability is obtained by placing concrete blocks on the carriages to which the back ties are connected.

The jib can be adjusted to any angle between 30° and 60° with the horizon, which admits of all blocks in longitudinal and cross walls being laid without moving the crane until a new section of work is commenced.

The gear for all motions is controlled from the covered platform which is attached to and rotates with the mast. Flexible steel wire rope is used for both lifting and derricking.

The results obtained from this crane are thoroughly satisfactory and similar arrangements for cranes of all powers up to 30 or to 40-tons render them available where lifting machinery of the ordinary type cannot be conveniently employed.

The concrete blocks laid by the derrick crane are produced by the plant illustrated and described at pages 30 and 38. This plant has also produced the blocks used in the formation of an extensive breakwater on the opposite side of the harbour; these were laid by a Titan of 35-tons power, similar to Fig. 5004.

FLOATING CRANES FOR BLOCK LAYING.—Although the water is frequently too rough for blocks to be set in pier, mole and similar work by floating cranes, a very large number have been laid by cranes similar to those illustrated by Figs. 5003 and 5007. They are however principally employed in handling artillery, locomotives, etc. and specially, in the formation of breakwaters, several examples of which might be mentioned, but that referred to at page 16 will perhaps be sufficiently typical

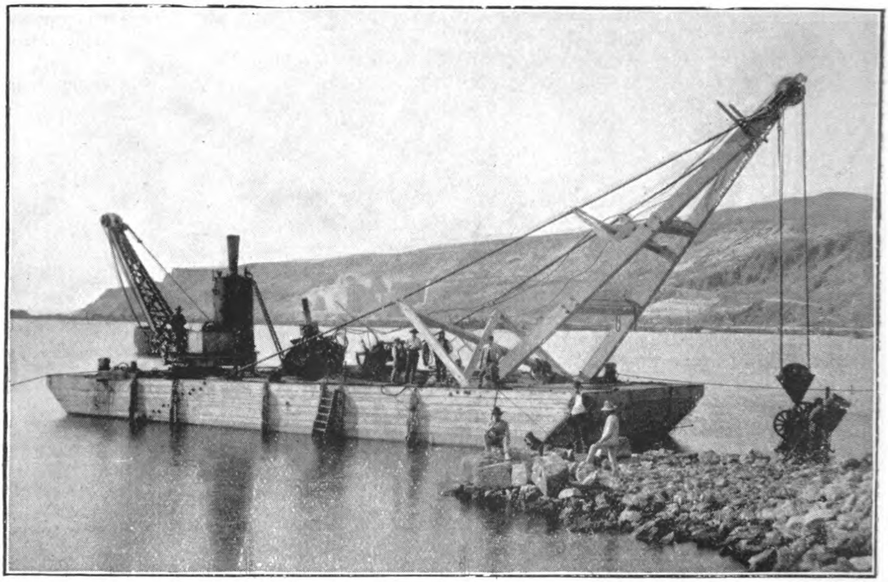


Fig. 5007.

FLOATING CRANE FOR DREDGING AND BLOCK LAYING.—The combination illustrated by Fig. 5007 is employed in the formation of a harbour and line of quay, as well as for ordinary service in the harbour, and eventual extensions.

The fixed jib crane, in the foreground, deals with weights up to 30-tons. A steam winch fixed at deck level, about centrally with the length of pontoon, provides the lifting power, and changes of position are effected by cable and winch, one of which is fixed at each corner of the pontoon. As the two cranes are never required to work at the same time, the winch is supplied with steam from the crane boiler.

The revolving crane at the other end of the pontoon is of 10-tons power and has quick speed for light loads in handling cargo, etc. and all appliances for grab dredging.

Grab dredger.—The 10-tons crane manipulates a grab (or dipper) dredger, of 1½-cubic yards capacity, of the construction indicated by Fig. 5111; this now prepares the bed for the concrete blocks, and will eventually be used for dredging the harbour and maintaining the requisite depth of water.

Pontoon.—This can be built in steel and delivered complete with machinery, or in sections, the machinery having been previously fixed temporarily, and marked for re-erection.

The timber pontoon illustrated, and all woodwork, was, however, provided by the purchaser from designs supplied in advance, together with the deck equipment of winches, fair leads, chains, anchors, etc.

This arrangement (suggested by the writer's firm) has been quite satisfactory.

The price of the machinery and ironwork for the 30-tons crane is about ... £570

The weight is about 18½ tons.

The price of the revolving crane of 10 tons power, with special base plate for attachment to pontoon timbers, is about £750

The weight is about 23½ tons.

The grab dredger bucket of 1½ cubic yards capacity, with automatic opening gear, costs £165

The deck equipment costs about £130

GOLIATH CRANES worked by steam, electric or hand-power, are usually indispensable in concrete-block making yards and scarcely less so in quarries and in many railway goods stations and industrial works, in lieu of an overhead traveller which frequently cannot be conveniently installed.

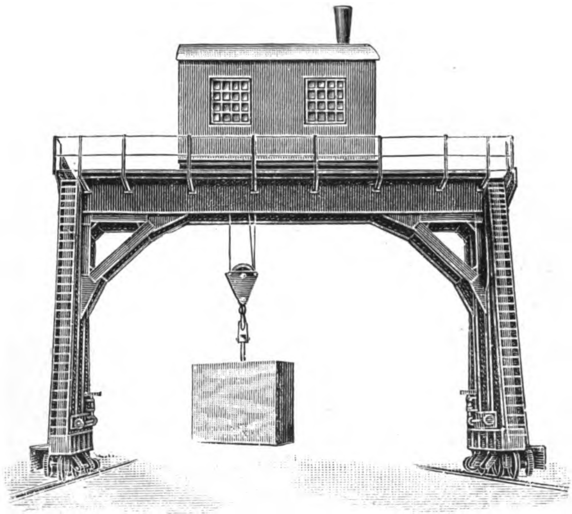


Fig. 500S.

GOLIATH STEAM CRANE of 50 tons power.—The crane illustrated by Fig. 5008 lifts, traverses, and travels longitudinally with a concrete block suspended, as indicated in the engraving, which it deposits on a block truck, similar to that represented by Fig. 5011, for transport to the Titan, floating or shipping crane as mentioned respectively at pages 25 and 26.

Dimensions and construction.—The span is 35-ft. and the clear height of lift 19-ft. The gantry is built of box section mild steel girders and is mounted on steel-tyred wheels, steel axles and springs, with heavy slide blocks and gun-metal bearings.

Machinery and speeds of working.—Power for lifting, cross traverse and for travelling longitudinally, is transmitted and controlled from the room which protects the engine and machinery. Access to this is afforded by ladders with hand-rail, shown in the engraving, and a railed platform on each side of the main girders.

The winch, with engines, boiler, feed water tank and coal bunk, are fixed on a platform constructed of steel girders and fitted with double flanged steel travelling wheels, steel axles, gun-metal bearings, etc.

The lifting gear is treble purchase, the winding drum is grooved spirally and coils the flexible steel wire rope without overlap; a powerful hydraulic brake is provided for the maximum load, and a strap brake for holding or lowering loads up to 10 tons.

Speeds of working.—The test load of 50 tons was manipulated at the under-named speeds:

Lifting	6 feet	per minute.
Longitudinal travelling	88 feet	,,
Cross traversing	22 feet	,,

High speeds for each motion are provided for loads not exceeding 10 tons.

Arrangement of tracks.—Three rows of blocks (3 blocks in each row) are each provided with one of these cranes which deposit the blocks on the special trucks represented by Fig. 5011, the tracks for the latter converging towards the block shipping crane, Fig. 5012.

PRICES OF GOLIATH STEAM CRANES.—The following figures represent the approximate cost of cranes similar in design and dimensions to that referred to:

50 tons	power,	£3,150,	and the weight	is about	100	tons.
40 tons	,,	£2,300,	,,	,,	70	tons.
30 tons	,,	£1,900,	,,	,,	50	tons.
20 tons	,,	£950,	,,	,,	28	tons.
10 tons	,,	£690,	,,	,,	20	tons.

GOLIATH ELECTRIC CRANES are not illustrated, and it will only be necessary to say here that, as a rule, they cost rather more and weigh rather less than those last referred to, power and proportions being equal.

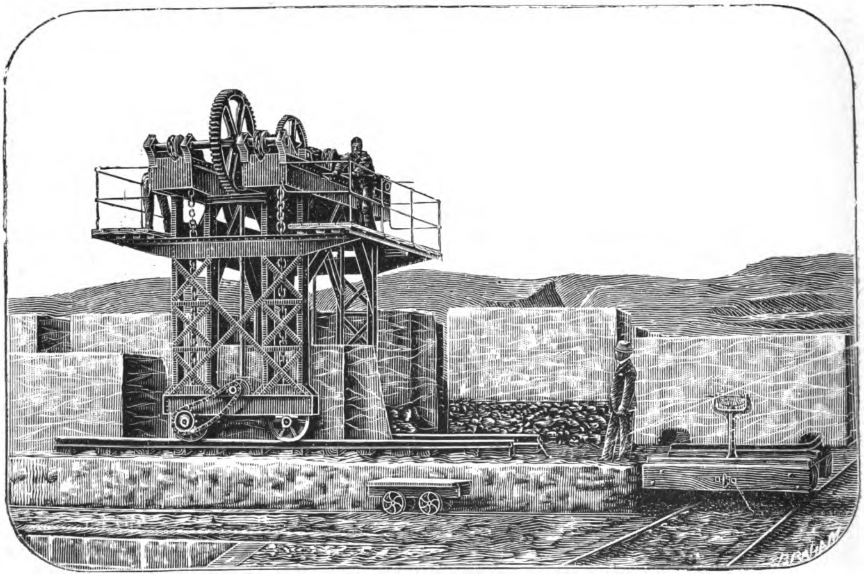


Fig. 5009.

GOLIATH CRANES WORKED BY HAND-POWER.—This system is found to be too slow and too costly in manual labour for general adoption, but where initial outlay must be limited and the daily output of blocks is comparatively small, these being lifted a few inches and traversed a short distance, cranes of the type now referred to have been quite satisfactory, it may however be mentioned, that where they have been used, unskilled labour is good and cheap, but engine drivers or mechanics cannot be obtained locally.

GOLIATH CRANE OF 40 TONS POWER.—The engraving Fig. 5009, with the following brief description, will convey sufficient information with reference to the construction of the plant and the method of working it.

Structure and machinery.—The gantry is built of wrought iron and spans 11 feet, the clear height being 10 feet; the under-carriages are fitted with double flanged steel travelling wheels and both the lifting and travelling motions are transmitted from the treble purchase winch which is fixed to the top main girders. The platform, with hand-rail around the winch, provides space for eight men, but six is the number usually employed.

Mode of working.—The Goliath passes between the blocks, lifts one clear of the ground and carries it to the block truck (shown on the right of the engraving) to be hauled to the Titan.

When one row of blocks has been delivered, the Goliath is traversed on to the block truck and transferred by it to the row which is then ready for delivery.

The tracks from the Goliath towards the block truck and that from the latter to the Titan have both a slight down grade.

The cost of a Goliath crane similar to Fig. 5009, is about £650

HAND-POWER GOLIATH CRANES, constructed of wrought iron or mild steel, are made of all powers and proportions, but taking 30-ft. span and 14-ft. high as convenient units, they can be obtained at about the under-named prices.

PRICES OF WROUGHT IRON HAND-POWER GOLIATHS.

Lifting power ... ... tons	5	10	15	20	25
Price of portable crane	£275	£375	£475	£550	£670
Price of fixed crane	£250	£340	£435	£510	£627

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

BLOCK TRUCK.—The frame of the truck shown in Fig. 5009 is built of steel girders with strong timber decking and cross cushions which support the block and leave a clear space between it and the truck platform. The wheels and axles are of steel, and the latter are fitted with heavy gun-metal bearings. The small truck in the foreground is one of those used for conveying the skips of concrete from the mixers to the block moulds.

The cost of the block truck is about £160

BLOCK SHIPPING PLANT.

The word "shipping" in this case includes the delivery of blocks, from the yard where they are made, to the barge or wagon for transport by water or land to the point where they will be finally deposited.

There are several arrangements of plant for this purpose much less costly than that now referred to (Figs. 5004 and 5009), some of which are illustrated and described at pages 37 to 40 and in Section II. of this series; but an examination of the following engravings and brief descriptions will show that nothing which forethought and experience could suggest has been omitted to ensure the efficiency which has been achieved.

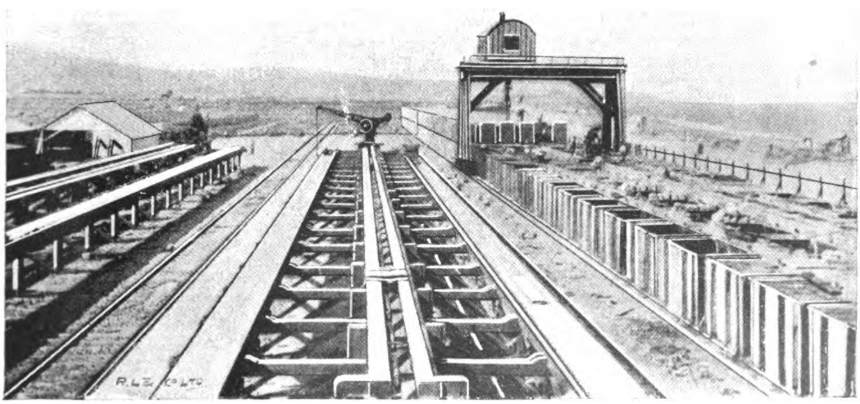


Fig. 5010.

BLOCK YARD STEAM GOLIATH CRANE.—Fig. 5010 represents a steam goliath Crane of 45 tons power, designed and built by the writer's firm, and a portion of the block yard in which it was employed.

Work performed.—As shown in the engraving, the Crane spans five lines of blocks and has the height necessary for stacking two tiers, and for clearing moulds which may be in front of blocks required for delivery, so that an ample supply of thoroughly seasoned blocks should always be available. Two of these Cranes were provided because they had to place the blocks on the block truck, Fig. 5011, which conveyed them to the Shipping Crane, Fig 5012, and can handle two blocks at a time, whereas that now referred to only deals with one.

Dimensions and construction.—The span of the gantry is 42-ft. 6-ins., the clear height is 28-ft. 3-ins., and the under-carriage is fitted with steel wheels, springs, etc. for travelling on longitudinal rails 46-ft. centre to centre

The structure is of mild steel box section girders with the necessary bracings and usual actors of safety for all parts.

Machinery.—The steam winch, equal to an ordinary working load of 45 tons, traverses across the gantry and furnishes power for travelling the crane longitudinally at a speed of about 88-ft. per minute with full load, and 132-ft. per minute light.

Steel is largely used in the construction of the winch and a hydraulic brake sustains the maximum load, a strap brake being provided to control the high speed gear for loads up to about 10 tons.

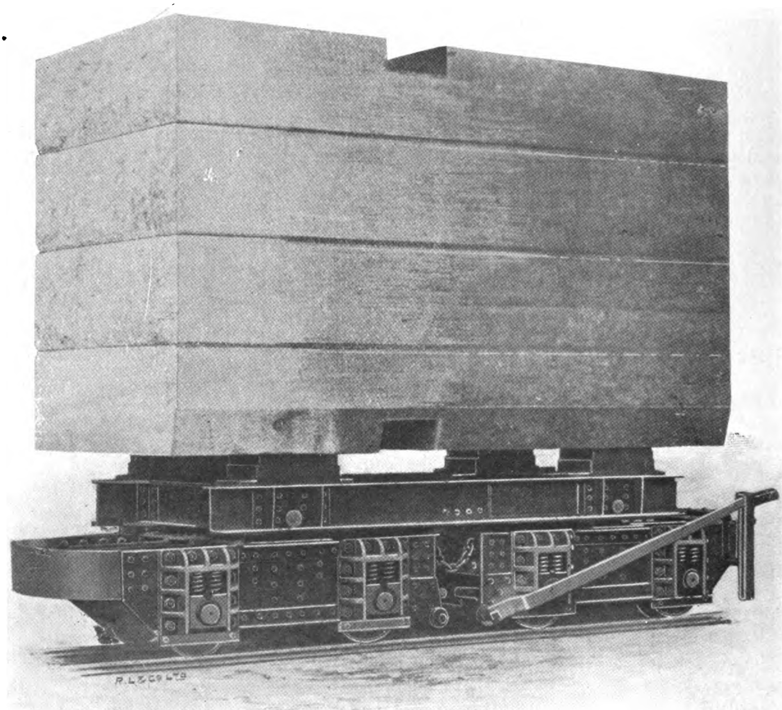


Fig. 5011.

BLOCK TRUCK.—The truck with its load ready for delivery to the shipping crane consists of a strong steel frame mounted on two swivelling bogies each with four steel wheels which are carried in massive steel axle boxes with springs. This arrangement was adopted to facilitate traverse over certain sharp curves which could not be avoided.

The truck is fitted with spring draw gear and hand lever brake; cushions across the decking giving the clear space required for manipulating the lifting appliances.

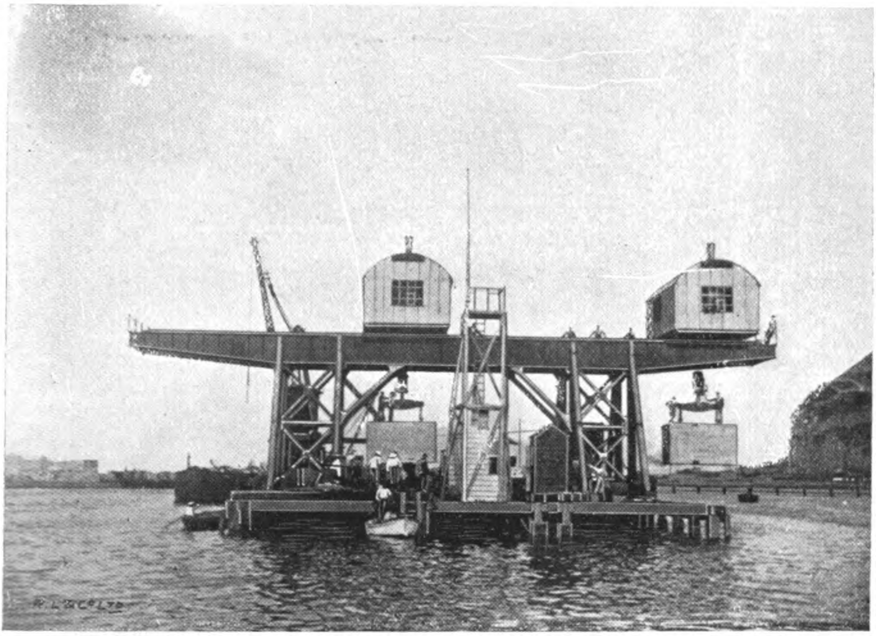


Fig. 5012.

BLOCK SHIPPING CRANE OF 90 TONS POWER.—The jetty on which crane is fixed is beyond the end of the block yards with floatation for barges on both sides. The working load of 90-tons consists of two blocks each weighing about 45 tons, which are conveyed to it by the block truck, Fig. 5011, and when lifted clear of it are traversed by the steam winches to right or left, between the end supports and deposited on barge for delivery to the Titan.

Dimensions and construction.—The height from rail level to the underside of main beams is 22 feet, the clear span between supports is 40-ft. and the cantilever at each side projects 25-ft.

The construction (allowing for increase in load and this being a fixed structure) is similar to that described in connection with Fig. 5010.

Machinery.—There are two steam winches, each of 45 tons power, and similar to those mentioned at page 21, which traverse the loads, separately or together, and deposit them on barge for transport to the Titan.

CANTILEVER BLOCK-SHIPPING PLANT.—The engravings Figs. 5013 and 5001, and the following description refer to appliances designed and built by the writer for dealing with concrete blocks, each weighing 40 tons, used in the formation of a breakwater in random work (pierres perdues).

Goliath crane.—A hand-power crane of the type Fig. 5009 for a working load of 40 tons, lifted the block clear of the ground and traversed and deposited it on a block truck for transport to the block shipping crane. In this instance—as in many others—the platform of the truck was level with the floor of the block making yard.

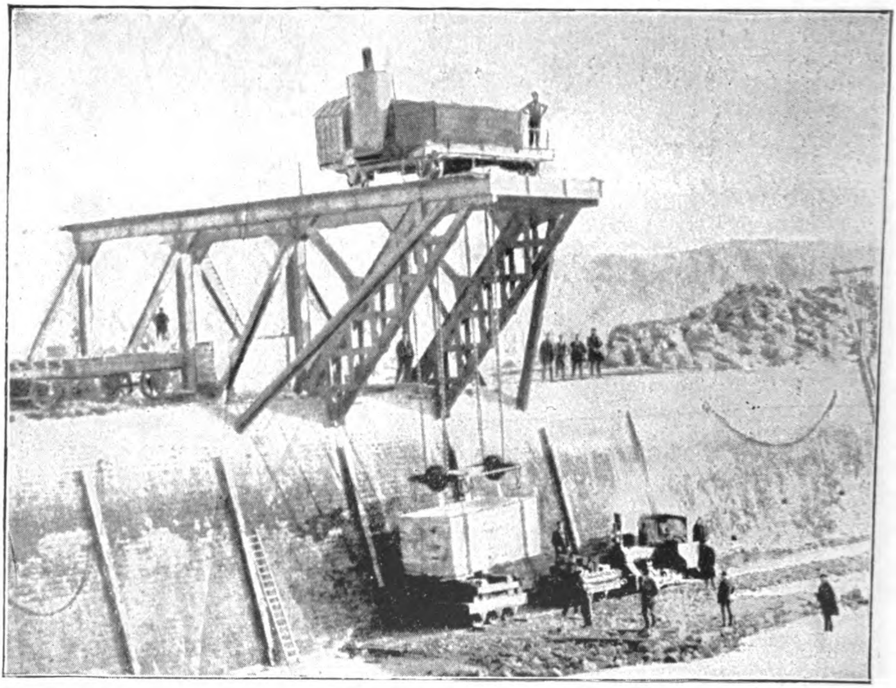


Fig. 5013.

The shipping gantry, Fig. 5013, was constructed of timber uprights and struts supporting a pair of wrought iron girders, with steel rails rivetted to their upper members for carrying the travelling crane, wrought iron lattice girder struts for the overhanging end, and gussets to tie the longitudinal girders to the timber uprights.

The overhead steam travelling crane lifted the block which had been placed under it, and traversed out into position for lowering on to the truck below, as shown in the engraving, and subsequently on to barge as mentioned further on.

Railway and trucks.—A temporary narrow gauge line was laid on the floor of the dock for conveying the block trucks (hauled by locomotive) from the shipping crane to the breakwater. The line was continued along a temporary staging from which the blocks were slipped to the front or to either side, and thus form the centre line of the breakwater, the staging being lengthened to suit the progress of the work. But so soon as the dock was filled with water the rest of the blocks were carried on barges and slipped as shown in Fig. 5002.

The trucks, each to carry one block, were built of timber, with platform to tip all round, taper cross pieces and gear for holding the block in position in transit, and for releasing it when desired.

The slip-barges used for completing the breakwater, after the dock had been opened for traffic, were built in timber—to carry one block—with flat bottom and deck, and provided with the necessary sliding pieces, slipping gear, chains, capstans, etc.

The barges were loaded by the shipping gantry and were towed into the position desired for launching the blocks.

Results obtained.—The work was completed within the contract time and considerably within the estimated cost. The plant was comparatively inexpensive and—for the most part—eventually saleable.

The cost of the block-lifting Goliath, with steel carriage, treble purchase winch, etc. to lift 40 tons and to traverse with that load by hand power is about £350

The cost of the block-shipping crane, Fig. 5013, including the overhead steam-travelling crane of 40 tons power, wrought-iron gantry girders, with gusset plates to connect them with the timber supports, heavy steel rails to carry the travelling crane, and wrought-iron lattice girders to support the outer ends of longitudinal girders, as shown in the engraving, is about £1450

The timber-work in the gantry, as well as the block trucks and slip-barges, were provided by the purchaser in accordance with drawings made under the writer's supervision.

LEWIS BARS, BLOCK LIFTING BEAMS, LIFTING CLAWS, ETC.—Appliances of this kind are usually designed by the Consulting Engineer or the Constructor of the plant, to suit the work to be performed, and vary too much to admit of them being adequately illustrated ; useful examples of the types generally used are, however, indicated in the engravings Figs. 5008, 5012, &c.

CONCRETE BAG WORK.—The appliances for this purpose consist of a wrought-iron or steel box with drop bottom doors, the attachments for opening and closing them, in any depth of water, being manipulated by the man in charge of the crane which lowers the box. This is usually a Titan or other crane provided for handling the concrete or stone blocks for which the bags form the bed.

The proportions and shape of bag boxes are adapted to the size and weight of bags, and the arrangements for opening the doors after bottom has been reached, or for dropping the bags from a convenient height, are outside the box and easily controlled from the surface.

COMPOSITION OF CONCRETE.—The undernamed proportions of materials, mixed in any of the machines referred to in this volume, have given most satisfactory results under the conditions mentioned.

It will be understood that sand, gravel or broken materials must be clean, and free from mixture with clay or other earthy matter.

Concrete for blocks.—The undernamed proportions have been largely used for docks, breakwaters, etc. :

Portland cement	1 part
Sand, or its equivalent...	2½ ,,
Gravel, Shingle, or broken materials ...	6½ ,,

Quantities per cubic yard of concrete.—2½ bushels of Portland cement, weighing not less than 112-lbs. per bushel, are required for one cubic yard of concrete, the other materials being in the above-named proportions.

But some reduction in the quantity of cement used is often made by placing large stones in the mould. If these are completely embedded in the mixed materials and not in contact with each other, the blocks so made seem to be in no way inferior to those in which the stone is broken and screened to size.

Measures for materials.—Care will, naturally be taken that these shall be arranged as conveniently as possible. As regards cement, waste is reduced to a minimum if it is delivered to the mixer in bags, so that if the mixing machine is half a cubic yard capacity, the bag should be made to contain 1¼ bushel of cement.

Concrete in Monolith or continuous wall.—For ordinary work, two bushels of cement for one cubic yard of concrete is usually sufficient, but if extra strength or resistance is required, as much as three bushels of cement per cubic yard of concrete may have to be used.

Weight of Portland cement.—As already indicated, a bushel of cement should weigh not less than 112-lbs. the measure being lightly filled (as in sifting into it) and, of course, strickled.

Test of Portland cement.—The following is usually considered satisfactory : A test piece 1½-in. by 1½-in. is moulded and placed in water as soon as it will bear handling. After seven days immersion it must not break under a tensional strain of less than 2½-cwt. per square inch of section.

PLANT FOR CANAL CONSTRUCTION.—Although few works are of sufficient magnitude to justify so large an installation of plant as that employed in the construction of the Chicago Main Drainage Canal, the following brief abstract from a paper on this subject by Mr. F. J. Lewis may be interesting in connection with the remarks on "Excavators and Conveyors" at pages 144 to 148, and probably suggest modifications which can be advantageously employed on other, and less extensive undertakings.

Nature and quantity of work.—The total length of the canal is 28 miles and has involved the removal of about 28 million cubic yards of glacial drift and 12 million cubic yards of rock, or about 40 million cubic yards in all.

The length of the portion in glacial drift is 13¼-miles, the width is about 202-feet at the bottom of the canal and 290-feet at water level. The length in rock is about 14¾-miles and the average width about 160-feet.

The canal has a depth of 26-feet at high water, the mean depth of water being about 24-feet.

Glacial drift.—This and the top soil throughout was removed, as far as possible, by scoops or scrapers; the rest of the work was done by steam excavators, grabs and steam cranes. The spoil was conveyed by trucks, travelling bands, or rope-ways, without handling, to dump or bank, as required.

The cost of the work, including excavation and disposal of the spoil, ranged from 4d. to 7½d. per cubic yard.

The rock was removed, as above indicated, to a large extent without blasting; rock drills driven by compressed air and explosives, only being employed when necessary.

CONVEYORS AND EXCAVATORS.—Some of the spoil was taken away by trucks and portable railway, but it was evident that the works could not be executed in the requisite limits of cost and time, without a large provision of plant specially designed for the different conditions to be fulfilled.

The arrangements adopted consisted principally of the use of steam excavators (see Fig. 5105) in conjunction with portable aerial tram line, travelling band, and boom conveyors, mounted on travelling carriages. These followed the steam excavator and were easily moved forward to receive the spoil from the excavator and deliver it at the distance and height required, without re-handling.

The efficiency of the plant is established by the fact that one set has dealt with 920 cubic yards of spoil in ten hours at a cost for labour, fuel, etc. of about 4d. per cubic yard for excavating and depositing at distances up to about 632 feet, and a height of 91 feet.

The portable travelling bands were made, in some cases, of strong india-rubber, supported by rollers which dished the band from the edges towards the centre, and others of a series of steel trays which carried the spoil up an inclined plane and discharged it at the height desired. As above indicated, both types of band elevator were mounted on carriages and moved forward as the work progressed.

PLANT FOR TRANSFERRING AND DEPOSITING SPOIL, MINERALS, ETC.—A portable steam or electric crane with a grab of the type Fig. 5040 or 5110, distributes over an area large enough for most purposes. This plant is economical in first cost and in working expenses, four steam cranes and grabs having handled 1,000 tons of spoil in four hours with a total cost in working expenses of about 20/-, and—as indicated elsewhere—the cranes are equally available for general service.

For traversing and discharging at distances beyond the capacity of the crane arrangement, conveyors of one or other of the types mentioned in the following paragraphs may be more suitable for the work to be performed. Each of these types are modified to suit local conditions, and as plant of this kind needs to be specially designed, the details mentioned under the heading "Information required" should be furnished as accurately as possible.

An aerial tramway carries the materials any distance and automatically dumps them at the point desired. This plant is inexpensive, easily moved and frequently answers every purpose.

A boom conveyor consisting of a long boom supported from a travelling tower and projecting beyond each side of it, commands a large area for deposit.

The boom is adjustable to the height and angle desired and it can be slewed, so that material can easily be distributed over the surfaces best adapted for its reception.

Travelling bands.—In some cases the spoil from the excavator or dredger is deposited on a band at one end and delivered by it at the height required at the other end, the power for driving the band being transmitted from the excavator, or from a separate steam or other motor, as may be convenient.

A travelling stage with cantilever incline, up which end tip trucks (brought by locomotive) are hauled by gear and tipped at the summit, has worked most successfully. The stage referred to was complete with engine and had two tracks; the cost of working and of maintenance were very low.

Information required.—The quantities and character of the materials dealt with. The distance to be traversed and the relative levels at which materials are to be received and delivered. The nature of the ground—and other conditions—are so diversified, that complete details should be furnished in order that the plant may be designed to give maximum efficiency with minimum working expenses and initial outlay.

CONCRETE MIXING MACHINERY.

However little resemblance there may be in the arrangement of concrete mixing machines, the mixing vessel comes into one of two categories, *i.e.* "continuous" or "intermittent" feed and delivery.

One of the systems may be more convenient than the other, under certain circumstances, but after more than 30 years experience in the construction and arrangement of all kinds of concrete mixing plant, and of observation on the results obtained, the writer has been unable to discover any appreciable difference in the quality of the output whether the machine is of the continuous or intermittent delivery type.

Cost of plant.—The initial cost of mixers for a given output, and the cost of operating and maintenance are usually in favour of the continuous system (represented by Figs. 5014 and 5016) but better adaptation to local conditions may well outweigh these relatively unimportant items.

Arrangement of plant.—It is usually much easier to arrange the mixers and machinery connected therewith, than it is to devise the most suitable appliances for quickly and cheaply conveying materials to the machines and depositing the freshly mixed concrete in moulds or otherwise. The work can usually be done by cranes, tram-lines (overhead or at ground level) conveyors, overhead transporters, cable-line, etc. all of which are referred to in this volume, but if difficulties should arise in connection with this important portion of the plant, they will, perhaps, be best solved in consultation between the engineer in charge and an experienced constructor who is familiar with the manner in which standard types of plant have been used and combined.

FIXED, PORTABLE AND LOCOMOTIVE PLANT.—Each type, is referred to in the following pages, but it may be well to point out that if the machines are fixed, the finished concrete has to be carried to the place where it is to be deposited, whilst if the machines travel, the materials must be brought to them, so that it is more a question of convenience than of cost of work performed.

When large quantities of concrete are required in dock walls or in blocks, fixed machinery may be preferable to portable, whereas the reverse may be the case for the formation of a long stretch of sea or river wall, or for depositing smaller quantities in detached sections This is prominently so where the mixer can traverse over the moulds and discharge direct into them, as referred to at page 31 to 33.

AUTOMATIC FEED.—The space at disposal does not admit of more than brief reference to the different arrangements which have been devised for automatically delivering the proper proportions of materials and water for each charge into the mixer hopper. All the machines now illustrated and described can be arranged to perform these operations automatically, but exception has been taken (not without reason) to this mode of feeding on the ground of possible inaccuracies, and the extra cost of labour for accurately measuring the materials is so small on each ton of concrete produced, that the advantage of automatic feed is perhaps less than, at first sight, it seems to be.

Combinations of feed machinery.—Amongst the arrangements successfully employed for saving labour, may be mentioned :

Bucket and chain elevators discharging into the mixer hopper.

Steam hoist with side opening measuring skip.

Jib crane with power winch and skip to deliver to mixer.

Electric motor attached to the mixer frame operating and travelling the machine, or any of the above-named combinations.

DIMENSIONS OF MIXERS.—A wish has often been expressed to have machines of larger capacity than those now referred to, but the results obtained in the few instances where standard dimensions have been exceeded, are by no means satisfactory.

The conclusion, therefore, is that it is better to have more machines of standard types and sizes, than fewer of larger capacity.

ELECTRIC DRIVING.—In large installations involving long lines of shafting which soon get out of truth, a separate electric motor for each line of shaft, if not for each machine, is frequently very convenient and invariably effects an appreciable saving in the total power required as well as in the cost of maintenance.

A single motor usually suffices if the mixing vessel only has to be driven, but if power is required for other purposes, such as travelling the machine (see page 32), raising the materials, hauling trucks, etc. it is frequently desirable to have a second motor, one for the mixing and the other for the other operations. Current is conveyed by overhead or underground conductors, as may be convenient.

INFORMATION REQUIRED.—If an opinion is desired with reference to the disposition and quantity of plant to be employed, the following details should be furnished together with any other which will be of service :—

Description of materials and the proportions in which they are to be used.

The quantity of concrete, or the number and weight of blocks to be produced in a given time.

The position and levels of the block making ground relatively with the approaches by which the materials will be brought to the mixers.

The position and levels of the block making ground relatively with those of the works to be constructed.

MATERIALS FOR CONCRETE.—If clean gravel or shingle is not available, a stone breaker of the type, Fig. 5132, will probably be required, with provision for screening and classifying the stone, and transferring it to truck, skip or barge for transport to the mixers.

If clean sharp sand cannot be obtained, granite, burnt ballast or other suitable materials broken up as last mentioned, and pulverised to the desired fineness in a revolving edge runner mill, as indicated in Fig. 5102, forms an excellent substitute.

CONCRETE MIXING.—M. Paul Mesuard advises that the quantity of broken stone to form concrete, and of lime or cement mixed with sand to form mortar, should just fill the interstices between the silicious substances.

The volume of these spaces is easily measured by pouring sufficient water into a receptacle to fill it, the water being then drawn off and the volume measured.

Proportions of cement.—The quality of the concrete or mortar will be too poor and its homogenity jeopardised if the quantity of cement or lime is insufficient, but it is more expensive and the quality is not improved if the cement or lime is in excess of the proper quantity.

Proportions of materials.—The present object being to deal with different types or mixing machinery, it does not come within the object and scope of the following remarks to discuss matters relating to proportions of materials, but it may be well to mention that the concrete foundations for the Forth Bridge Piers contained not less than $4\frac{1}{2}$ and not more than $6\frac{1}{2}$ cubic feet of Portland cement to each cubic yard of concrete, and about the same quantity (or rather more) of sand, the rest consisting of Whinstone broken and screened as above described.

Resistance and weight of concrete.—The resistance of the above-named concrete, to crushing, was 50 tons per square foot, and the weight was about 37 cwt. per cubic yard.

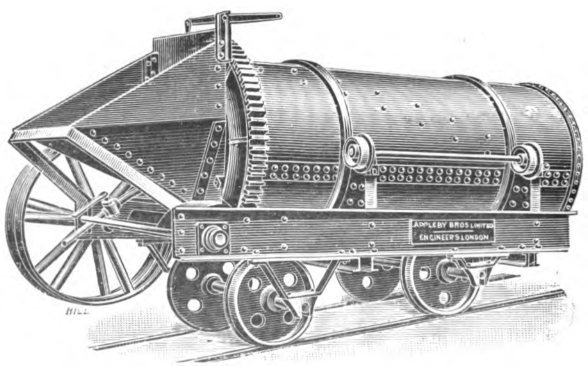


Fig. 5014.

CONTINUOUS ACTING MIXERS.—Fig. 5014 represents an improved arrangement of the system devised by the late Mr. Ridley and built by the writer's firm. The machine is driven by steam or other power, or by electric motor attached to the carriage, in either case with or without automatic feed and appliances for altering the inclination of the revolving cylinder.

Output.—Power driven machines are in work in all parts of the world turning out 100 to 120 cubic yards of concrete or more, per 10 hours when driven by an engine of four nominal horse power.

Construction.—The cylindrical mixing vessel built of rolled steel plate is open at both ends and provided with straight or spiral mixing plates (or blades) secured to the shell internally. The cylinder is fitted with a strong spur ring at its upper end and is revolved by pinion, shaft and pulleys for driving by steam power and is supported longitudinally by a pair of rollers on each side, bearing on the two steel bands which also serve to strengthen the shell.

The hopper for materials is provided with a sliding door worked by a lever for controlling the discharge of materials into the mixing vessel, as desired.

The machine is entirely self-contained, the steel girder frame which carries the mixing cylinder and gear being mounted on travelling wheels as shown.

The water supply is usually delivered from a galvanised iron tank—not shown in the engraving—with appliances for the water supply necessary for each charge of materials; if the supply is not by gravitation, a small pump will be required.

Mode of working.—The materials are delivered into the fixed hopper and thence to the mixing cylinder which is slowly revolved, the internal blades continuously taking up and turning over the materials in their passage in a spiral direction, thoroughly incorporating them by the time they reach the lower end where the concrete is discharged.

The price of the portable machine as illustrated and described is about ... £125

A galvanised iron tank (with apparatus) and feed pump costs about ... £15

FIXED CONTINUOUS MIXING MACHINES.—These are precisely as last described and illustrated, excepting that the travelling wheels and their accessories are omitted, and the girder frame is adapted for bolting to timber or masonry, the height of which above ground level is usually sufficient for discharging the concrete direct into truck or skip.

The price of fixed mixers capable of producing 100 to 120 tons of concrete in 10 hours is about £105

CONTINUOUS MIXER WITH MEASURING BINS.—A simple and efficient arrangement for obtaining uniformity in proportion of materials with minimum supervision and labour consists of a machine of the type Fig. 5014, with two pairs of bins fixed over the mixer hopper and drop doors opening into it, with appliances for controlling the deliveries.

The larger bin of each pair contains the broken stone, shingle, etc. and sand, and is generally one cubic yard capacity, the other is of the size required for the specified proportion of cement. These bins being side by side and each pair opening simultaneously (whilst the other are being refilled) it follows that the contents become distributed before they enter the mixing vessel.

The time occupied in filling the bins is rather less than that required for complete mixture and delivery at the lower end, so that with the two pairs of bins, the operations can be continuous if so desired.

Compartment skips.—A similar result is obtained by using skips with divisions for each material, the skips being lifted by crane (or otherwise) as indicated in Fig. 5020, but this method is less rapid and satisfactory than the double bin arrangement above referred to.

TRAVELLING ELECTRIC CONCRETE MIXER. — Fig. 5015 represents the most recent development of concrete mixing machinery, in which the mixing vessel is of the type described later on under the heading "Messent Closed Mixers," but the combination now illustrated is designed by Mr. A. H. Owles, M.Inst., C.E. and built by the writer's firm.

This very efficient plant is referred to in "Transport" in the following terms:—

"Before proceeding to describe the machines it may be well to direct attention to the reasons which led Mr. Owles to devise this ingenious system. The objects to be attained were the perfect mixture of materials, which is essential, and the immediate delivery of the quite freshly made concrete into the block moulds; also (from an economical point of view), to ensure the work being performed rapidly and economically as regards cost of labour. The importance of these conditions being unerringly fulfilled is evidently necessary when we consider the vast

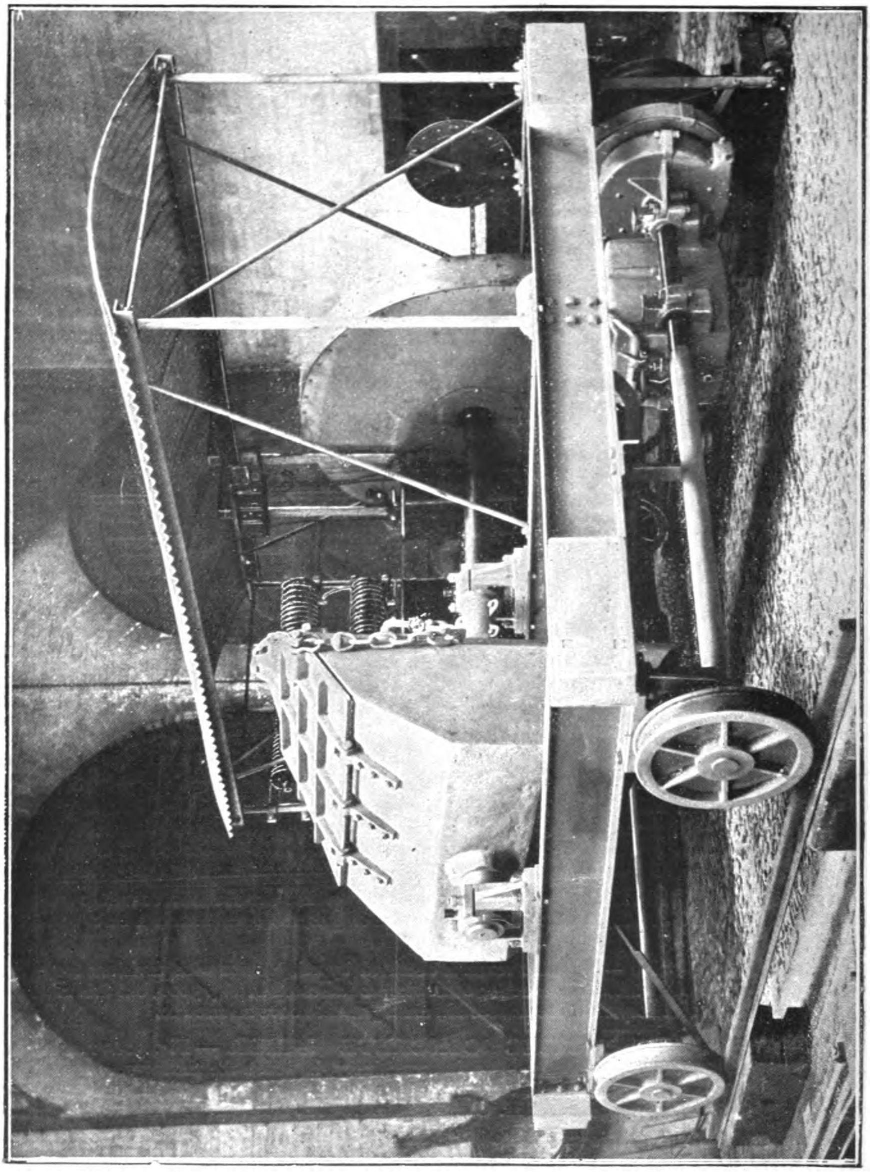


Fig. 5015.

mass of materials required for the making of concrete blocks, and that these blocks are now almost universally employed in the construction of harbours and docks.

The machine illustrated herewith, which a representative of "Transport" recently had an opportunity of examining in the works of the above-named firm, embodies the most recent improvements, the outcome of the inventor's experience with similar plant used in the largest of the three block-making yards for the construction of Dover Harbour, the arrangements for which are under his charge. The mixing vessel, the capacity of which is one cubic yard, is of the well-known Messent type. It is mounted on a strong steel framed carriage, provided with two electric motors, one of which revolves the mixing vessel, whilst the other gives a travelling motion to the carriage, so that the operations of mixing and travelling can be performed simultaneously. The proper charges of materials are fed into the mixer from hoppers and the charging door closed: the machine is then travelled to and over the block mould, the mixing vessel being meanwhile rotated by the motor provided for that purpose. The number of revolutions made are indicated by a dial within view of the attendant, and when about fifteen revolutions are registered—the number required to ensure complete mixture—the mixer motor is stopped (the machine being then in position over the block mould), the mixed concrete discharged, and the machine returned for another charge. Brakes are supplied both to the mixer turning gear and to the traveller motion.

Several other types of machines produce good concrete, but there can be no doubt that the plant now illustrated leaves nothing to chance, every provision being made for the production of perfect concrete at a remarkably small cost for labour."

Motors.—These are of the slow speed enclosed waterproof type required for the rough duty and exposure which is unavoidable in a blockyard. They start easily with considerable overload, and are provided with efficient rheostats.

The engraving shows the motor for travelling the carriage, with which is combined an ingenious and reliable device for maintaining the gear in proper pitch. The travelling wheels are of steel and the axle bearings are fitted with springs.

The motor for revolving the mixing vessel is at the opposite end of the carriage, the main driving wheel being enclosed in the wrought iron casing on the right.

The pointer indicates on the dial the number of revolutions made by the mixing vessel, and is in view of the driver.

Speed of travelling.—These machines travel at a speed of about 6 miles per hour, and a strap brake, controlled by the driver's foot, prevents over-running.

The mixer track is above the block moulds, and the gauge admits of the block being lifted vertically by any suitable crane, usually by a Goliath crane similar to that shown in Fig. 5008

Output.—This is about 120 cubic yards of concrete per day of 10 hours, each charge being mixed during the time occupied in travelling from the charging platform to the block mould. Thus, whilst the output does not much exceed that of a fixed mixing machine, no locomotive or other hauling appliance is required; there is large saving in time and labour, and the concrete is delivered, quite fresh, direct from the mixer.

The price of the machine as above described is about £550

The weight is about 10 tons, and the cost of packing for shipment and delivery f.o.b. is about 5 per cent.

HIGH SPEED MOTORS.—If smaller and higher speed motors are used, the total cost of plant may be somewhat reduced, but the balance of advantage is in favour of low speed motors. See "Notes on Power Transmission."

CLOSED CONTINUOUS ACTION MIXER.—The machine illustrated by the diagram drawing Fig. 5016 (Taylor's patent), differs from those previously referred to inasmuch as the mixing vessel, although closed, can be charged and discharged whilst revolving continuously; like other mixers the materials can be mixed dry before water is admitted These machines are made fixed as well as portable, and in various combinations as regards modes of feeding, dimensions, &c.

Mode of working.—In all cases the specified proportions of materials are filled into the feeding hopper immediately above the mixing cylinder on the right, and are admitted by a sliding door into the cylinder, where they are firstly mixed dry. The prescribed quantity of water (automatically measured) is then admitted by the pipe connecting the supply tank with the hollow perforated shaft on which the vessel rotates, and a few more revolutions suffice to completely incorporate the materials.

The vessel is emptied by simultaneously opening all the discharge doors, through which the concrete is delivered into skip, truck, or shoot, as the case may be, The discharge doors being closed, a fresh charge is admitted and the process repeated as described The engraving clearly indicates the manner in which these operations are controlled by the attendant on the mixer platform.

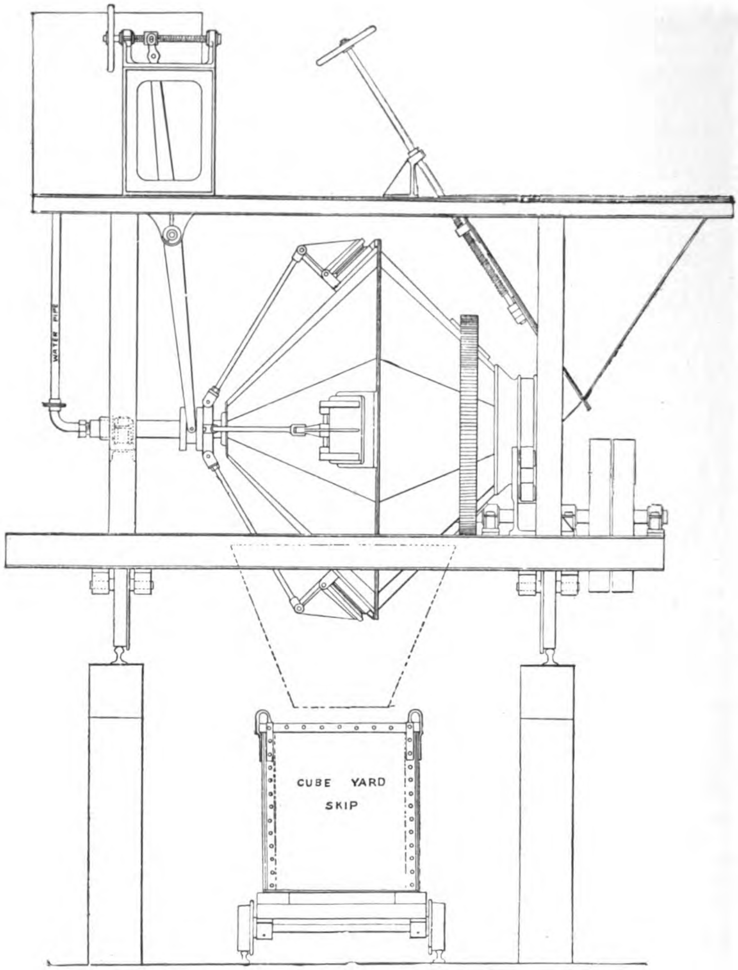


Fig. 5016.

Mode of driving.—That shown in the engraving is usually convenient, but other arrangements are easily devised to suit exceptional conditions.

Cost of labour.—The machine is worked by one man, and having regard to the large output, it is clear that labour forms a very small item in the cost per cubic yard of well-mixed concrete.

PRICES OF TAYLOR CONCRETE MIXERS.

Output per hour	...cubic yards	10	24
Power required	horse power	6	8
Price of fixed machine		£165	£225
,, portable ,, ...		£180	£240
Extra for jib crane and winch		£30	£35

The prices of trucks for carrying the concrete range from ... ... £7 to £10

MIXER WITH ENGINE AND BUCKET AND CHAIN ELEVATOR (not illustrated).—This forms a complete plant, including driving power, mixing machine with ladder and bucket elevators which take up the materials at ground level and deposit them in the hopper for treatment as above described.

The machine is complete with engine and boiler and (if desired) the portable plant can be arranged to travel on track of ordinary gauge by self propelling gear, so that it follows up the work, or is easily traversed to a new location.

The price of a machine to produce 10 cubic yards of concrete per hour is about £450

For an output of 24 cubic yards of concrete per hour the machine costs about £550

CLOSED CONTINUOUS MIXER (Gauhe's patent).—These closed vessel mixing machines are made for output capacities ranging from about 4 to 40 cubic yards of concrete per hour. Both portable and fixed machines are usually complete with elevator box, which serves as a measure for the prescribed quantity of materials, and appliances for raising and automatically delivering them into the mixer.

The mixing drum is built of steel plates with internal steel blades which raise and drop the materials during the revolutions of the drum, firstly in their dry state, and finally after the proper charge of water has been admitted, thus producing complete incorporation.

Charging and discharging.—The discharge door is opened by the attendant so soon as the drum has made the number of revolutions (10 to 15) necessary for complete mixture and appliances are provided for closing this door and automatically opening one at the base of the feed hopper which admits materials to the mixing vessel without stopping the machine. The hopper being re-filled as soon as it has been emptied, the operations are continuous and controlled by one attendant.

PRICES OF FIXED GAUHE CONCRETE MIXERS.

Capacity in cubic yards per hour	10	15	30
Driving power required ... ... horse power	2	4	6
Price of machine with elevator	£157	£220	£300
,, ,, without elevator	£97	£125	£185

PRICES OF PORTABLE GAUHE CONCRETE MIXERS.

Capacity in cubic yards per hour	10	15	30
Driving power required ... ... horse power	2	4	6
Price of machine with elevator	£192	£260	£340
,, ,, without elevator	£135	£190	£275

ELECTRIC CONCRETE MIXERS (Gauhe's patent).—A portable machine with elevators, as above described, but with enclosed type electric motor, counter-shaft and speed reducing gear, slide-rail for motor, starting switch, resistance and accssories for driving all motions, to produce about 16 cubic yards of concrete per hour costs about ... £375

The price of a similar machine, but equal to an output of about 26 cubic yards of concrete per hour, costs about £465

CLOSED MIXERS WITH INTERMITTENT ACTION.—The excellent quality of the concrete produced by machines of the types, Fig. 5015 (Messent's) and Fig. 5017 (Lee's) is too well known to need more than passing reference, but it may be well to point out that although the mixing vessels differ in shape, there is little or no difference in their action, output, or cost of working.

The cost of installation and maintenance may be in favour of the Lee system Fig. 5017 but not sufficiently so to be of much importance.

MESSENT CLOSED MIXERS.—These well-known machines are made either fixed or portable, and in many combinations as regards mode of driving, and appliances for feeding and delivery, but in all cases the capacity of the mixing vessel is about 1 cubic yard, and of the same shape as the electrically driven machine illustrated by Fig. 5015.

The mixing vessel is carried on a central axis and revolved by gear, this peculiar shape having been adopted to ensure the materials being turned over four times in each single revolution, so that complete incorporation should be effected in a few revolutions of the mixer. Strong hinged doors are provided at top and botton of the vessel, respectively for filling and emptying.

Output and working expenses.—These necessarily vary with local conditions, facilities provided, and so forth, but the average output of each machine worked by steam power may be expected to be 80 to 100 tons of concrete per day, three unskilled men will usually attend to one machine or (circumstances permitting) five men to two machines.

The prices of steam driven machines vary with the arrangement of the installation. but each mixer vessel with gear for driving by engine or electric motor will probably cost about £100

Hand-power machines with four men turning the mixing vessel, two men filling from trucks and a boy to attend to the water supply, will turn out about 50 tons of concrete per day.

The price of hand-power mixers of this type is about £120

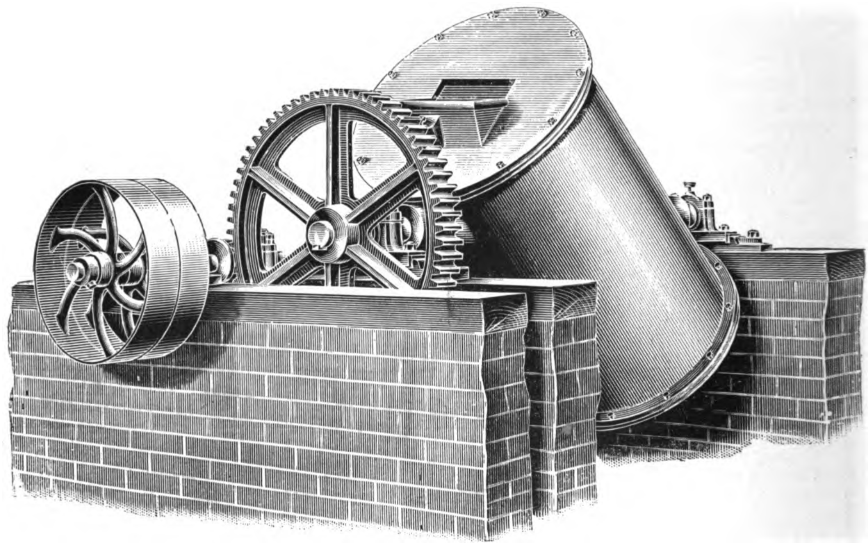


Fig. 5017.

CLOSED INTERMITTENT ACTION MIXER (Lee's system).—The machine illustrated by Fig. 5017, originally designed by the late Mr. Henry Lee, is well known as the most simple form of closed mixer, and if the action is studied, it will be evident that materials placed in a cylinder hung as this is and set in revolution, must be quickly and completely incorporated.

The cylindrical mixing vessel is carried on a steel shaft which passes through it diagonally, and is supported in bearings at each end. The cylinder is completely closed by covers at top and bottom, in which doors are conveniently placed for charging, discharging, and for fastening.

The mode of driving, feeding, &c. usually adopted is so clearly shown in the engraving that this need not be described in detail. The arrangements for fixing and feeding are modified as circumstances require, but something similar to those indicated in Fig. 5019, are very often suitable.

Output and working expenses.—The foregoing remarks apply equally to this machine.

The cost of the "Lee" mixer under conditions similar to those mentioned for the Messent system is, for each machine, about £90

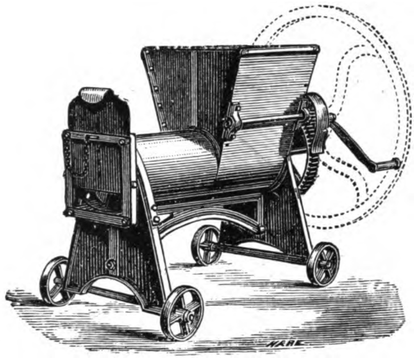


Fig. 5018.

HAND-POWER CONCRETE MIXERS are similar in action to those already described, and produce thoroughly mixed concrete in less time and with a smaller quantity of water than is required for shovel mixing.

A fly wheel on the mixer shaft equalises the effort on the handle, and a door at the delivery end is useful when the full charge is not used as mixed.

The price of a portable machine is	£10	0	0
Extra for fly wheel	£1	0	0
Extra for end door	£0	10	0
Extra for set of spare mixer blades	£0	10	6

CONCRETE MIXING AND BLOCK PLANT No. 1.—As already pointed out wide variations in the arrangement of machinery and in modes of transport must frequently be made, but that illustrated by the diagram drawings on page 39, with certain modifications to suit local conditions, some of which will be referred to, may be regarded as fairly representative of modern practice in the arrangement of block making plant employed in the construction of dock or harbour works of moderate extent.

BLOCK MAKING PLANT.—Fig. 5019 represents plant, designed and built under the writer's direction, to turn out 300 to 400 tons of concrete per day, for making blocks, each weighing about 30 tons, required for the formation of a breakwater about a mile long, and subsequently for the construction of an extensive mole on the other side of the harbour. The above-named output has, however, often been largely exceeded.

Arrangement of plant.—The stone, broken and screened to size at the quarries, is conveyed over an easy down-grade track in tipping trucks to the mixing platform where it is deposited in bins of ample dimensions, below the elevated track shown in the engravings (front elevation).

The sand and cement are brought, at block yard level, to a double track steam driven lift which raises these materials to the mixer platform.

An edge runner crushing mill was erected on the platform for pulversing rock, in case the supply of sand should prove to be deficient, but it has rarely been necessary to use this mill.

Steam power.—The whole of the machinery is driven by shafting and gear, as shown in the engravings, and, in this connection, it may be well to mention that the supply of fresh water being limited, the engine was made surface condensing and a portion of the sea water used for condensation is delivered into the tank which forms the roof of the engine room, and flows thence to the mixer platform. Similar arrangements have been adopted in other cases where the supply of fresh water is deficient or unreliable.

Light railway.—The temporary line from the mixers to the block moulding ground is slightly down-grade, so that haulage in both directions is quite light. The position of the tracks are, of course, altered from time to time to suit the progress of the work.

Repairing plant.—There were no local facilities for renewals or repairs when this plant was put down, and the small equipment of tools, saw-bench, etc. indicated in the engraving, have been extremely useful.

Quarry and block-lifting plant, such as stone breakers, light railway materials, trucks and locomotives, block lifter, block trucks, Titan for laying the blocks, etc. being illustrated and described in the present volume and in Section II. of this series, need not be referred to here in detail.

The concrete mixing machines of the Lee type (illustrated and described at page 36) are driven from a line of shaft and each is provided with clutch and lever for starting and stopping, and with a hopper into which the materials are delivered at platform level; these together with the proper quantity of water for each charge (automatically measured in a tank above the platform), are transferred to the mixing vessel through a sliding door operated by the attendant and after 10 to 15 revolutions of the mixer, the thoroughly incorporated concrete is delivered into turn-over skips, or trucks, as shown in the engraving.

CONCRETE MIXING AND BLOCK PLANT, No. 2.—The machinery is similar to that last referred to, but—to use the only ground available to best advantage—it was necessary to raise all the materials by steam driven lifts from ground level to the stone breaker and deliver them by gravitation to the mixer platforms, the former being at a higher level than the latter.

The stone breakers are of the type illustrated by Fig. 5132, and the screened materials are delivered to the mixing platform by shoots.

The concrete mixers are of the construction last described and are arranged and operated as shown in Fig. 5017, but the concrete is delivered into turn-over trucks, and is conveyed by overhead roads from which it is tipped direct into the block moulds.

CONCRETE MIXING AND BLOCK PLANT, No. 3.—In this case the mixers are of the Ridley type, Fig. 5017, and the stone, broken and screened, at the quarries is brought in side tip trucks, hauled by locomotive, to the mixers, where it is raised by bucket and chain elevator to the mixer platform.

There are some interesting features in other portions of the plant designed and supplied by the writer's firm, amongst which may be mentioned the block shipping plant and the block setting Titan, each for handling 80 tons blocks; these are illustrated respectively by Figs. 2156 and 2150 in Section II. of these volumes. There are also some specially designed time and labour saving arrangement of tracks, electric inclines, &c.

Quarry machinery.—This consists principally of narrow gauge temporary track connecting the quarries with block yard, and the usual equipment of locomotives, side-tip trucks, tipping skips, &c.

QUARRY CRANES.—There is one locomotive crane of 12 tons power, of the type Fig. 5123, one of 7 tons, and the others of 3 tons power.

The whole of the stone being required for concrete making, the shot holes are arranged to shatter the rock and reduce work in the stone breakers; the explosives being also selected with this object, most of the work could be done by the lighter cranes.

CONCRETE MIXING AND BLOCK PLANT No. 4—Fig. 5020 represents a portion of a large plant, designed and built by the writer, primarily for use in the construction of extensive harbour and dock works, carried out by a foreign government, and subsequently as part of the permanent installations for traffic.

The construction of the works occupied about 8 years, and since then the cranes have been employed as originally intended.

There were some exceptional features in these undertakings, but similar appliances have been usefully employed on the quays under circumstances differing widely from those now referred to.

The work performed consisted, in the first instance, in the construction in monolith, deposited behind sheet piling, of concrete walls forming the two sides and one end of the dock, and subsequently in making concrete blocks which were laid to a little below normal water level. Finally (ordinary building materials not being available) the mixing machinery was employed in producing a considerable quantity of concrete used in the construction of extensive warehouses, foundations, machine shops, foundry, &c.

Materials.—These were brought partly by rail but chiefly by water and delivered near to the point where the concrete was deposited, or blocks made, this being (under the then existing conditions) considered preferable to the long lead which would have been necessary if the usual central mixing and block ground arrangement had been adopted.

Machinery employed.—Each set of machinery consisted of a Lee mixer, carried in a wrought iron portable tower, and driven and fed by a locomotive steam crane as illustrated, the plant being moved forward as the work progressed.

A Goliath crane, with quick speed, transferred the concrete from the mixer to the moulds, treble purchase gear being provided for manipulating the blocks.

Turn-over skips were used for handling materials and Murray drop-bottom skips for delivering the concrete in situ, or into the moulding boxes.

The steam crane lifts and deposits the materials and simultaneously drives the mixer in the manner shown in the engraving.

The derrick motion for varying the radius of jib, and the travelling motion, both controlled from the drivers platform, furnish great facilities for depositing the concrete precisely where desired.

The mixer tower is provided with platforms around the filling hopper and starting gear, also with pump to supply the specified measure of water, and all accessories required to form a complete and independent concrete mixing plant.

The discharge door is manipulated by the man who attends to the skips containing materials and those for the concrete.

Wrought iron Goliath crane.—This spans the block making floor and is open at both ends to admit of the skip being discharged direct into any of the moulds, a central gangway being laid for delivering the finished blocks, as indicated in the engraving.

The lifting and traversing motions are worked by hand power, the total number of blocks to be handled in any one place being insufficient to justify the outlay for steam power machinery, nor was the latter necessary for piling and delivering timber, for which these cranes were finally employed.

Cost of plant.—The prices of the component parts of this plant which are described and illustrated, will be found under their respective headings, but the total cost may be estimated to amount to about £1250

The total weight is about 42 tons.

ELECTRICALLY DRIVEN BLOCK YARD PLANT.—It is claimed that, for large works, there is great convenience as well as saving in fuel and labour in supplying electric power from a central generating station to the fixed or variable points where power is from time to time required.

An installation of this kind dispenses with the supply of fuel, water, etc. to a number of small engines, the removal of ashes etc. and electric current is transmitted through considerable distances with so little loss of power, that the claim for economy seems to be fully established.

There is, of course, no sort of difficulty in arranging electrical driving for stone breakers, screens, cranes, pile drivers, and the numerous other machines now commonly employed by Contractors, and if travelling electric concrete mixers of the type illustrated by Fig. 5015 are used, the mixing ground need only be provided with the appliances for accurately measuring the specified proportions of materials, cement and water, and for charging the mixing vessel. The rest of the work, up to delivery at the block mould, is done by the mixing machine which is in charge of one attendant.

CONCRETE MAKING TRAIN.—A further development of travelling concrete mixing plant successfully used in the formation of long stretches of retaining wall, which had to be put in quickly and in very limited space on each side, may be briefly described as follows :

A train of wagons containing supplies of stone, sand and cement for a day's work, or more, and a special self-propelling wagon were brought into position for commencing work, the special wagon carrying the concrete mixing machine, steam power, and a belt conveyor which receives the concrete direct from the mixer and deposits it in trench, or block moulds, as the case may be.

The conveyor boom is pivoted to swing vertically or horizontally, so that the freshly mixed concrete can be distributed over a large area, very quickly and without any manual labour.

Arrangements of this kind are obviously adopted with advantage where space is limited, and if the use of a steam crane and grab for transferring the stone and sand from the wagons to the mixer platform, is admissable, the work is carried out very rapidly and at remarkably low cost. Failing this (as in the case referred to) the materials are wheeled or trammed along a gangway over the wagons.

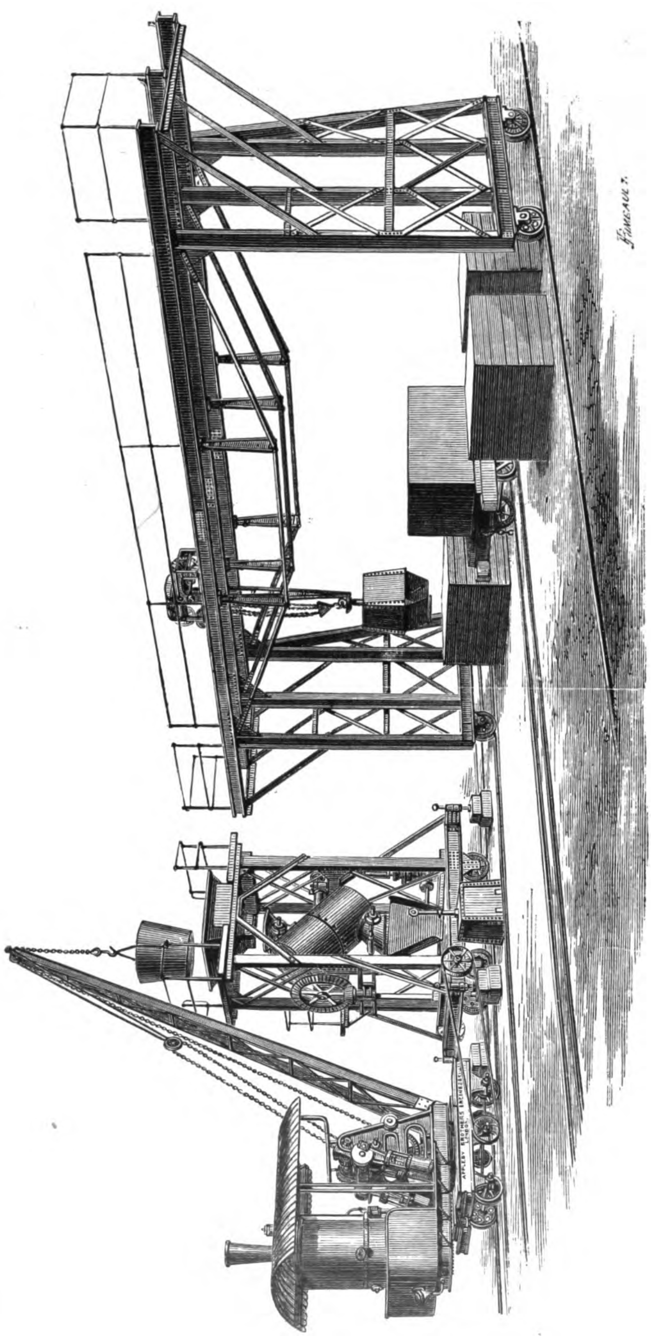


Fig. 5020.

PILE DRIVING PLANT.

PILE DRIVING MACHINES.—The well-known form of pile engine frame illustrated by Fig. 5021, whether arranged to work by hand, steam, or electric power, serves for pitching as well as for driving piles, vertically or at an angle ("batter") as required, and has long ago replaced the "ringing engine" formerly used, excepting for driving a few isolated piles to no great depth, and is now almost universally adopted in works carried out under British supervision.

Mechanical arrangements.—Although a frame of the construction indicated in the engraving is generally suitable for pile driving by hand, steam or electric power, the mechanical details (described further on) vary considerably, and the types may be classified as the chain, the direct acting steam, and the electric systems. It is essential that each should be as little liable to derangement as possible, and that the parts should be light enough, consistently with stability, to be easily moved and quickly erected.

The questions of total weight and vibration are also of importance where—apart from their cost—sufficiently substantial staging or working platform cannot be easily provided.

These conditions are perhaps best fulfilled by one or other of the machines now illustrated, or by an electric driver such as that described at page 44. But where it is necessary to keep the pile "lively" by rapid succession of blows, the direct acting system, referred to at page 43, will probably give the best result. The objection to it, which in some cases has been fatal to its use, is the higher cost of the complete machine, the much greater weight of parts, and the necessity for staging of a kind that cannot always be conveniently provided.

The water jet referred to at page 48, is a great aid when driving piles in compact strata.

Information required:

Height of frame, or length of pile to be driven.

Weight of monkey to be provided.

The gauge and minimum radius of curve or angle of track required.

Details of work to be performed and of power (if any) to be supplied.

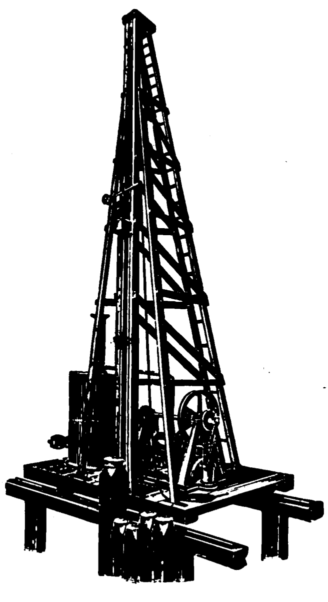


Fig. 5021.

STEAM. WINCH PILE DRIVERS.—The frame of the machine, Fig. 5021, is of pitch pine, tied and strengthened by ironwork, and mounted on travelling wheels which can be adjusted to follow any curve or angle of track.

The head pulley is grooved for chain or wire rope and provided with turned steel spindle, gun-metal bearings and lubricators, and the leaders are faced with iron.

A strong single purchase double cylinder steam winch is fixed on the driving platform, a brake controls the run out of chain and the same lever operates a clutch on the chain barrel. The boiler is of the vertical cross tube type, built of steel plates double rivetted and complete with chimney and the usual fittings; the hydraulic test pressure is 150-lbs. per square inch, and the working steam pressure is usually about 70-lbs. per square inch.

The following approximate prices include the machine complete with chain, nippers, trip gear and monkey.

PRICES OF STEAM WINCH PILE DRIVERS.

Weight of monkey	ton	1	2
Price of machine as described	...	£212	£235
Approximate weight and measurement	tons	8	10

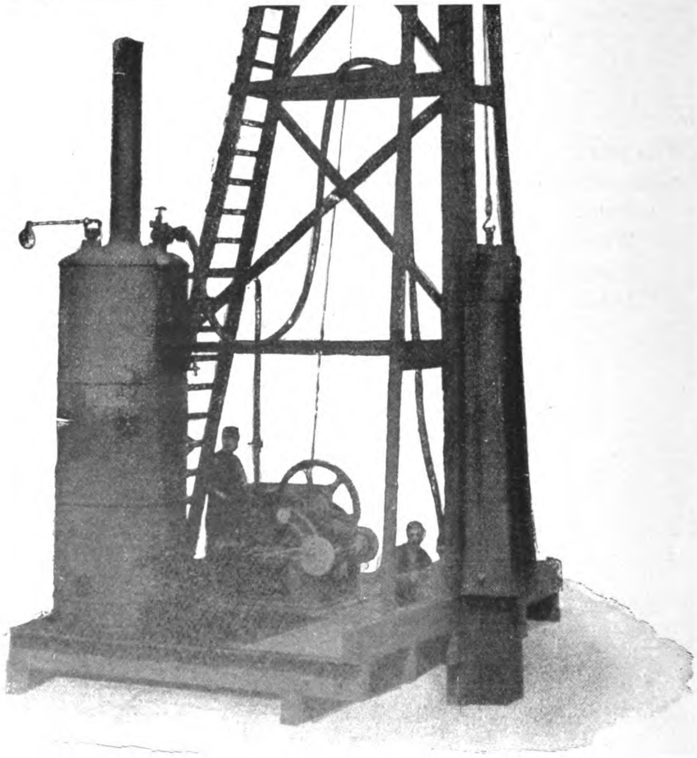


Fig. 5022.

DIRECT-ACTING STEAM PILE DRIVER.—The engraving Fig. 5022 illustrates the latest improvement in direct-acting pile drivers, the principal features of which are that:—

The piston rod always rests on the top of the pile which is being driven, whereby the whole weight of the monkey and piston assists in the operation and prevents the pile rising (as it often does) when driven in running sand.

The flexible steam tube, which connects the monkey with the steam boiler, does not move up and down at each stroke of the monkey as in other pile drivers, but descends only with the pile.

By the first-named improvement much time is saved and extra driving power is obtained, and by the second the heavy wear and tear of steam tube and risk of accident from breakage are avoided.

Construction.—The objects last referred to are attained by making the piston rod of forged cast steel, and drilling it to carry steam to the lower end, the flexible steam tube being connected to the upper end.

The monkey, as will be seen in the engraving (which represents it at rest), slides on the piston and falls when the exhaust valve is opened, but on arrival at the bottom, steam is admitted through the piston rod into the interior of the monkey and causes it to ascend for the next stroke. The steam admission and exhaust valves are operated from the pile driver platform.

The speed of working depends principally on the length of stroke, and varies from about 20 to 40 blows per minute.

Outfit and prices.—The pile engine frame is built of any height, that now referred to being pitch-pine to drive piles of any length up to 30 feet, and is complete with chain, or steel-wire rope, head-pulley and travelling wheels. The machinery comprises the patent monkey with valves, vertical boiler and flexible connections, valve lines, etc. and the cost of the complete machine, with hand or steam power, winch for pitching piles and manipulating the monkey will be found below.

PRICES OF DIRECT-ACTING PILE DRIVERS, FIG. 5022.

Weight of monkey ... ... tons	½	1	1½	2
Price of machine with hand winch	£210	£300	£350	£430
,, ,, steam winch	£240	£320	£390	£480

The cost of packing for shipment and delivery f.o.b will be about 5 per cent.

DIRECT-ACTING STEAM MONKEY.—If it is desired to use an existing pile engine frame, or to build one locally, in order to save cost of freight and import duties, or for other reasons, the monkey, as illustrated in Fig. 5022, with planed guides can be supplied, ready for attachment to the leaders and complete with valves and flexible tube at (about) the undernamed prices.

PRICES OF DIRECT-ACTING STEAM MONKEYS.

Weight of monkey... ... ... tons	½	1	1½	2
Price of monkey only	£65	£95	£115	£130

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

ELECTRIC PILE DRIVERS.—The weight of machinery, boiler, etc. and the vibration inseparable from the reciprocating action of a steam driver, frequently present difficulties which are overcome by the use of electrical appliances. They drive at least as rapidly as the well-known steam machine, and the fact that the motive power is supplied by a wire or cable (no fuel or water being required) is often greatly in favour of this system.

Construction.—The frame and under-carriage are built of timber or steel and arranged in the same manner as those for steam pile drivers (see Fig. 5021). The travelling wheels can be adjusted to traverse any curve or angle of track, the frames are arranged to drive vertically or on the "batter," and the machinery can be constructed for working a monkey of any weight.

The principal departure from ordinary practice is the substitution of an electrically-driven winch with the necessary switches, etc. for rapid operation, and a powerful electro magnet, instead of the steam winch and nippers in general use. Nippers and trip gear can, however, be used if desired.

Mode of working.—The magnet and monkey (or ram) are firmly connected by switching on the current when they are in contact. The lifting motion coming into operation simultaneously

with this contact, the monkey is raised to the height desired for fall and, when this is reached. the monkey is detached by switching off the current; this operation also reverses the motion of lifting drum, so that the magnet follows the monkey and is re-connected as before. The switches for these operations are controlled from the winch.

The voltage of current available (if any) should be stated, in addition to the details mentioned at page 42.

PRICES OF ELECTRIC PILE DRIVERS.

Weight of monkey ... ... tons	1	$1\frac{1}{2}$	2
Height of pile engine leaders ... ... feet	40	40	40
Price of machine	£525	£625	£700

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

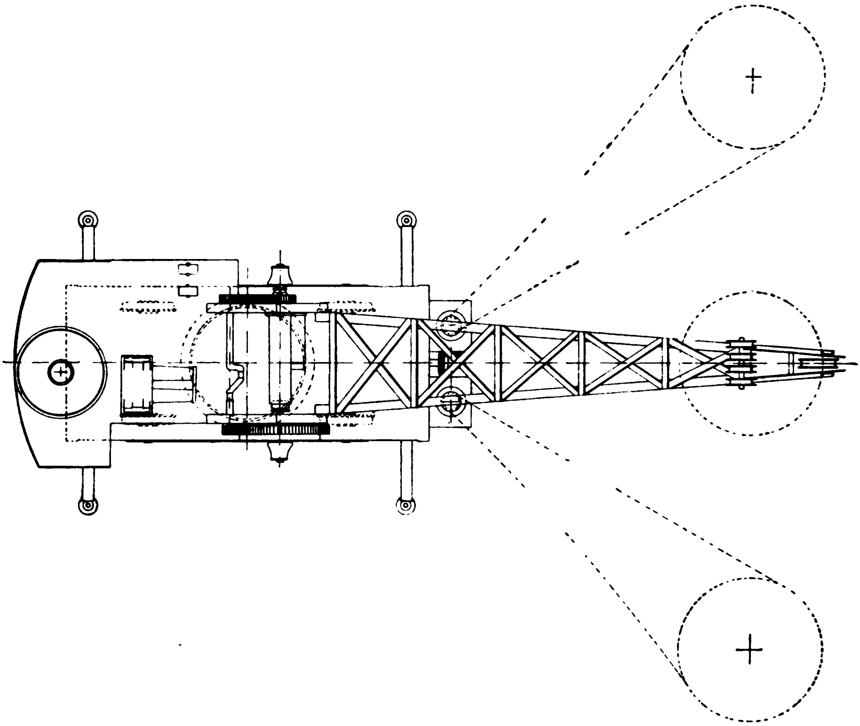


Fig. 5023.

STEAM CRANE, PILE DRIVER, AND PILE SCREWING MACHINE.—Combinations of machinery are, by no means always desirable, but sometimes, as in the instance now referred to, they may be used with considerable advantage.

The conditions to be fulfilled were as follows:

A quantity of timber piles had to be driven and (subsequently) iron piles had to be screwed in a locality where labour was extremely unreliable both as to quantity and quality, the work had to be carried out quickly and the working season was limited.

The materials had to be unloaded from craft, and under all the circumstances, it was decided that a steam crane specially arranged, so far as steam pile driving and pile screwing were concerned, would be the most suitable kind of plant to be provided, the crane being in any case required for service on completion of the works.

The machinery employed consists of a steam crane of 10 tons power, of the type, Fig. 5037 with steam derrick motion to vary the range of jib from 16 to 27-ft. and gear for travelling by its own steam power, the under-carriage being fitted with buffers and draw gear for hauling rolling stock, also with girders extending beyond each side, at both ends of the carriage.

The ends of these girders are provided with feet adjustable by screw and ratchet lever to give the requisite stability in whatever position the crane may be working and to counteract its tendency to move under the strains incidental to pile screwing.

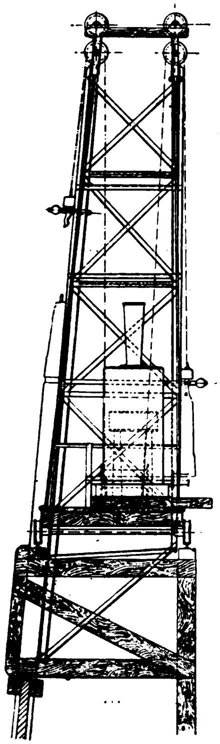
Pile driving appliances.—A rough timber frame with leaders and top pulley is constructed by the purchasers to suit the work to be performed and the crane is brought into position for the crane chain to be passed over the pulley. The crane gear, arranged as hereafter described, is used for pile driving, so that there is no alteration or addition to the crane and it is free at any moment for its ordinary work. Another arrangement of leaders is referred to under the heading "steam crane and direct acting pile driver," but that now described is usually the best and the cheapest.

The monkey weighs 1 ton, and is lifted and released by the well-known nipper and trip gear as illustrated in Fig. 5021. The lifting barrel is loose on the shaft and is connected to it by a claw clutch, the necessary fittings being provided for preventing over fleeting and for sustaining a pile when required. Capstans keyed on each end of the barrel shaft can be used for pile driving or pile pitching.

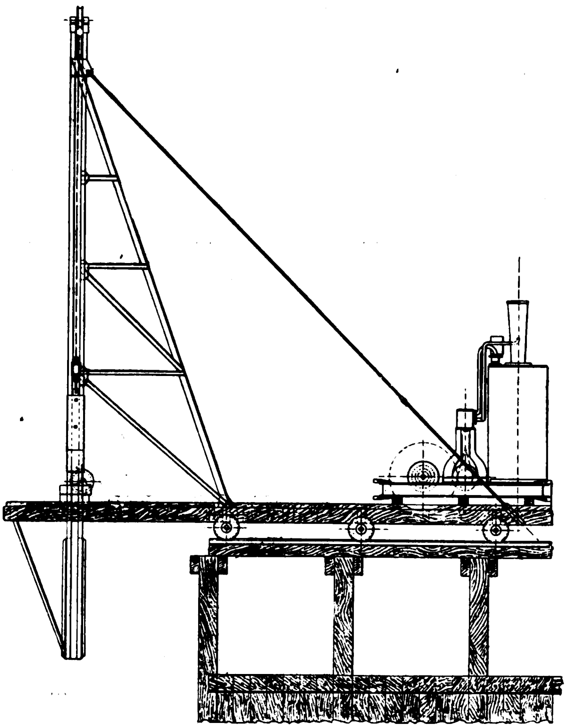
Pile screwing appliances.—These are attached to the under-carriage and arranged to give a fair lead between the pile screwing head and a pair of capstans carried in front of the under-carriage, which, when a pile is being put down, are driven by power transmitted from the crane engines. See Fig. 5023. This compact and efficient combination saves a considerable initial outlay for plant, freight, duty, etc. on the machinery required for pile driving and pile screwing which would be useless and quite unsaleable when the work is completed.

The cost of the plant is about £1000

The total weight, exclusive of some counterweight (scrap iron) which is provided at destination is about 32 tons, but for ascertaining the cost of freight, the total in weight and measurement should be estimated to be about 70 tons.



End elevation, Fig. 5024.



Side elevation, Fig. 5025.

TWIN STEAM PILE DRIVER.—The diagram engravings Fig. 5024 and 5025 are side and front elevations of plant which completes a timber stage or pier as the work progresses, and dispenses with floating pile drivers by utilising the portion just completed for further operations.

Positions of piles.—The piles forming the inner line are driven vertically and those on the outer side are on the batter, with sheet piling between the leading piles, as hereafter described.

The longitudinal lines of piles are, in this case, 8 feet apart, the spacing transversely being 9 feet, and these were well braced as soon as driven. The sheet piles were then driven, thus finishing this portion and leaving it ready for decking and for putting in the next section.

Arrangement of plant.—As indicated in the diagram Fig. 5025 two light steel pile driving frames, braced in the usual manner, are fixed on a strong under-carriage which overhangs the front pair of travelling wheels about 12 feet. The vibration (or springing) of these frames is counteracted by the adjustable tie rods between the top of each frame and the rear of the under-carriage.

The height of the frames in the plants now referred to was 30 feet and, as will be seen, they extend to about 7 feet below rail level for driving the sheet piles, the lower end of the leader being stayed to the front of the under-carriage, but all these dimensions are capable of indefinite variation.

The top pulley at the upper end of each leader frame is used for pitching piles, and the lower one carries the monkey rope ; ladders from the platform give the necessary facilities for oiling, etc.

Pile driving engine.—One machine of the type described and illustrated at pages 164 and 165 of Seetion II. supplies the power for driving both lines of main piles and the sheet piles, and provides ample counterweight for the overhanging weights, monkey, etc.

A capstan on each side of the engine frame serves for pitching piles, and a simple device is provided for holding the monkey up until it is again brought into operation after the pile has been pitched.

Each leader frame is equipped with its own monkey weighing 1 ton, self gripping and releasing nippers, rope, etc. ; the rope drum is operated by a very efficient friction clutch, devised by the writer, for this class of work.

This arrangement of clutch admits of the rope remaining attached to the monkey, when the number of blows per minute may be increased about 50 per cent.

The machine travels on rails fixed on timber frames, and two of these frames are used so that a length can be transferred from back to front as the work progresses.

Speed of working.—This can be varied to any extent up to about 20 blows of the monkey per minute.

The price of the machine, with water tanks, coal bunk, corrugated iron roof is about £450

STEAM CRANE AND DIRECT-ACTING PILE DRIVER.—The following description relates to a plant designed for use in the construction of extensions to existing docks, the crane to be taken over, on completion of the extensions, for quay service alongside others of the same type.

Work performed.—Piles 30-ft. long are driven by a 1-ton (1000 kilos.) direct-acting steam monkey, water under pressure being supplied at the pile point and the plant being complete with leaders and the above-named appliances, and steam travelling motion for moving along as the work proceeds.

Plant employed.—A steam crane of 5 tons power, similar to that illustrated by Fig. 5037, mounted on a travelling under-carriage fitted with a special steel structure similar to an ordinary steel pile-driver stage (the weight of which is carried in the socket which usually supports a jib), steel jib, large head pulley for steel wire rope, and steel leaders tied to the jib and revolving bed, the crane gear being used for adjusting the position of the monkey, pitching piles, etc.

Hydraulic pressure is delivered at the pile point, to aid penetration, by a double-acting steam pump fixed on the revolving superstructure near to the boiler. See also page 48.

The direct-acting monkey is supplied with steam from the crane boiler.

The crane jib is of steel and is complete with tie rods, etc. to replace the special jib and pile-driving appliances when the crane is taken for dock service.

The cost of this special plant is about £1000

The approximate weight is 30 tons.

FLOATING PILE DRIVERS.—Any of the machines referred to in the foregoing or following pages are easily arranged for fixing on a pontoon or barge, for putting down piles, effecting repairs, etc. in situations outside the range of the ordinary appliances.

Any barge (usually provided locally) with sufficient stability can, of course, be used, and whether the machine shall be fixed at one end or at the side, or removable to either position, is purely a matter of convenience.

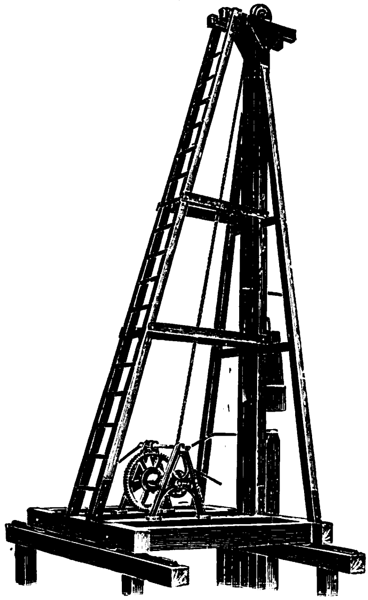


Fig. 5026.

HAND-POWER PILE DRIVERS.—The frame is built of pitch pine and strengthened by iron knees, etc. as indicated in the engraving; the fittings consist of a strong hand winch with brake, grooved chain sheave, bearings and accessories, chain, self-acting nippers, monkey of the weight specified and trip gear controlled from the working platform, or automatically.

Adjustable travelling wheels can be provided to follow any curve of track or traverse at any angle.

PRICES OF HAND-POWER PILE DRIVERS, Fig. 5026.

Weight of monkey	tons	½	¾	1
Height of frame	feet	24	24	24
Price of machine	...	£36	£42	£50
,, extra height	per foot	13/-	15/-	17/-
,, adjustable travelling wheels	...	£3	£4	£5
,, crab and ironwork only	...	£20	£25	£30

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

WATER JET FOR REFRACTORY GROUND.—It is now well-known that a jet of water at a pressure of 20 to 40-lbs. per square inch, ejected at the point of the pile, greatly accelerates the speed of driving, and the piles so put down are probably more firmly embedded than those driven in the ordinary manner, without the jet.

First use of the water jet —The circumstances under which the writer was called upon to devise and supply the necessary appliances are as follows:

A large number of piles had to be driven in strata which, at an average depth of about 3-ft. below the bed of the river, was impenetrable under ordinary methods, although far from being reliable for foundations. Long drops, rapid blows, and the heaviest monkeys only shattered the

heads of piles, without perceptibly increasing penetration at the point, but all difficulties vanished when the water jet was brought into operation. This is many years ago and the origin of the system has been lost sight of, but the work first performed by it has been remarkably successful.

Appliances used.—These consist of a steam pump and one or more iron gas tubes attached to the pile or, in some cases (but exceptionally) embedded in it. The lower end of the tube is open and near to the point of the pile shoe; the water pressure is conveyed by a flexible pipe connection between the pump and the upper end of the iron tube.

The effect of the jet is simply that it disturbes a small area of the ground through which the pile is being driven and causes it to close round the pile as it descends.

Pressure of jet.—In connection with the foregoing remarks it may be well to point out that the hydraulic pressure needs to be varied to suit the nature of the strata and the depth below the surface of sand to which the pile must be driven. The pressure of jet required at the pile point to ensure the best result, may range from 25lbs. to 75lbs. per square inch, but an effective pressure of 30 to 40lbs. (say 35lbs.) per square inch is usually satisfactory. It is however desirable to provide pumping capacity equal to the higher pressures, and the difference in cost is too small to be worth consideration.

Efficiency of piles driven by this system.—This is fully established by the fact that if the supply of water pressure is stopped for any length of time, before the pile is driven home, it is by no means unusual to find the sand collected so tightly around the pressure pipe (and necessarily around the pile) that even the small smooth pipe cannot be withdrawn without passing another jet pipe down alongside it to free it for removal.

The cost of the appliances rarely exceeds about £50 and the speed of driving has been increased more than tenfold, with great reduction in cost, wear and tear, etc.

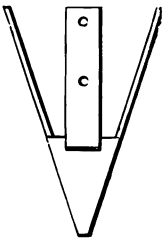


Fig. 5027.

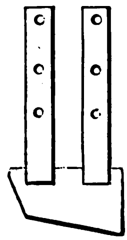


Fig. 5028.

PILE SHOES WITH CHILLED IRON POINTS.—Fig. 5027 represents the shoe for square, gauge or staging piles, and Fig. 5028, that bevelled on one side, for sheet piling, both being attached to the timber pile by wrought iron straps as shown. The weights of shoes and prices of materials vary so much that prices cannot be tabulated but they are easily ascertained if the kind and approximate weight of shoes required is defined.

PILE CUTTING MACHINES.—Appliances for cutting piles to bring the tops to a uniform level, whether above or below water line, are substantially as described below, but the work varies so much that what has been quite satisfactory in one case is often quite the reverse in another, the details are, however, capable of endless modifications.

The machinery employed consists, for the most part, of a circular saw specially toothed and fixed on the lower end of a vertical shaft which is adjustable in height and driven from above, appliances being provided for putting on the cut quickly, or otherwise as desired. In some cases rather rudimentary arrangements attached to the steam pile driver have answered every purpose, but if the quantity of work to be dealt with will justify the outlay, a far better result is obtained by having the machinery on a special trolly with its own driving power and sawing machinery.

ELECTRICAL PILE CUTTING MACHINES.—If a supply of current is obtainable, an electrically driven plant will be the most satisfactory, in ease of manipulation and efficiency.

Information required.—In the absence of drawings or sketches with figured dimensions, the undernamed details should be supplied. The size of largest pile, and kind of wood to be cut. The extreme range of saw vertically, or the depth below piling stage at which it must work. The distance horizontally from centre of pile engine track to outside of pile.

CAPSTANS.

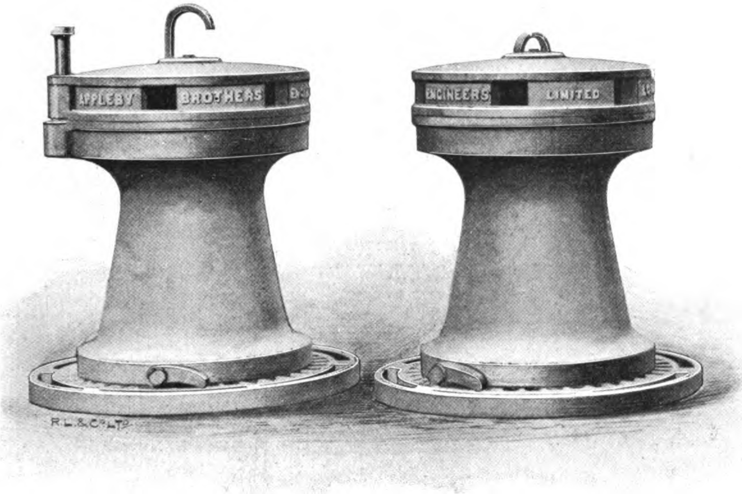


Fig. 5029. Fig. 5029A.

This subject having been dealt with at pages 167 and 168 of Section II, with illustrations of steam capstans, the present remarks apply only to capstans of the types represented by Figs. 5029 and 5029A, which are in use in many, docks, harbours, &c.

The Capstan, Fig. 5029, is provided with gear which doubles the power and halves the speed of warping, and can be in operation until the inertia of a large ship hes been overcome; it is then detached and the warping continued at the higher speed. The capstan, Fig. 5029A, is not fitted with this gear.

STEAM AND ELECTRIC CAPSTANS.—Although both those illustrated are worked by manual power, either of them can be adapted to work by steam or electric power as well as by capstan bars, the revolving head being made with metallic or hard wood whelps, as desired.

STATION TRAVERSERS.

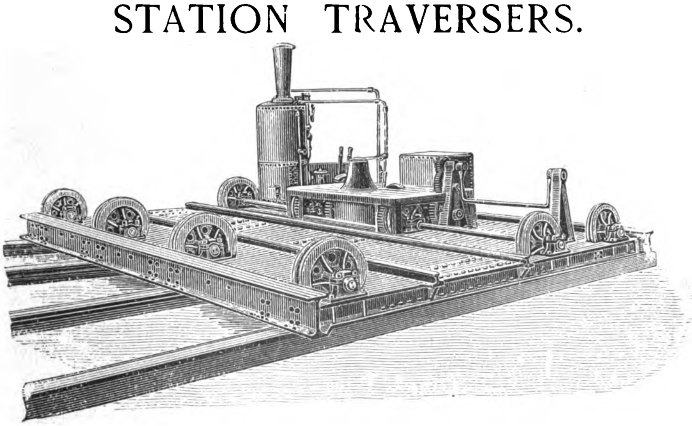


Fig. 5030.

LOCOMOTIVE STEAM TRAVERSERS for transferring rolling stock from one line of track to any other, must usually be specially designed for the work to be performed, but the essential features will probably not differ very widely from those indicated by Figs. 5030 and 5031.

Traversers for main stations are usually carried on rails at the same level (or nearly so) as the lines served, folding ramps being provided which form a set of inclined planes between the traverser and main line rails.

Platform and machinery.—The framework of the traverser, is built of rolled steel girders, strongly braced and decked with chequered plate.

The platform is complete with boiler, engines, and gear which transmits motion to the travelling wheels for moving between the points to be served, the vehicles being hauled on or off the traverser by the steam driven capstan shown in the engraving. It is carried on ten steel tyred wheels, with all appliances for driving them, and in this case (as in some others) hand gear is provided for use when it is not worth while to get up steam.

Capacity and dimensions.—The traverser, Fig. 5030, carries 50 tons and the dimensions are 25-ft. 6-in. by 21-ft. but these proportions are varied indefinitely to suit circumstances.

Information required.—This should include dimensions, weight and gauge of rolling stock, as well as clear indications with reference to the type of traverser desired.

ELECTRIC LOCOMOTIVE TRAVERSERS.—Figs. 5030 and 5031 and the foregoing description apply equally to steam or to electrically driven traversers, the alterations being merely the use of motors instead of steam power, and some modifications in the proportions of gear. Where current is available it will almost certainly be utilised for this purpose.

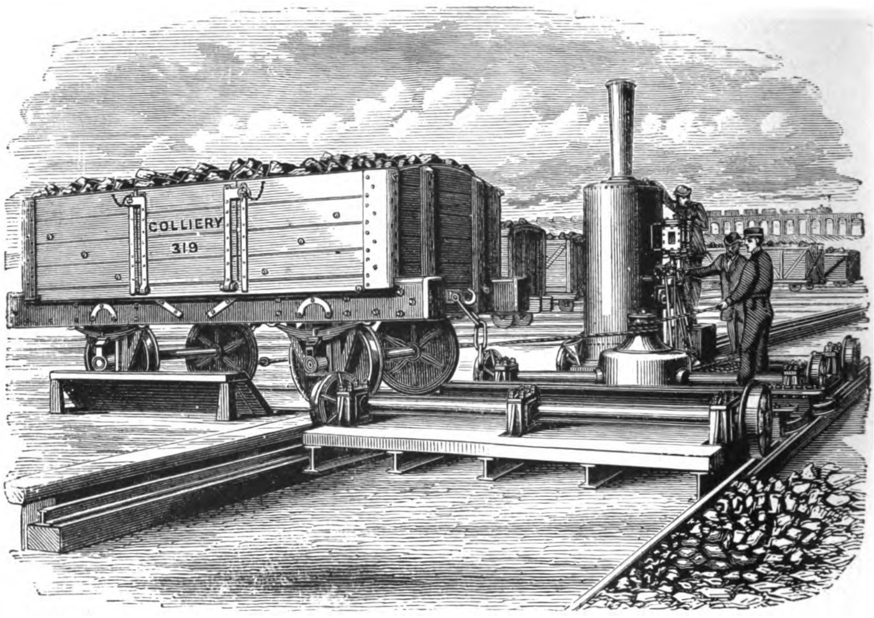


Fig. 5031.

TRAVERSERS FOR LOCOMOTIVE AND CARRIAGE WORKS, coal and mineral depôts, goods stations, etc., are frequently carried on rails slightly below ground level, so that the height of the traverser rails corresponds with that of the main line, as indicated in Fig. 5031.

ROPE OR SHAFT DRIVEN TRAVERSERS.—In some cases it is more convenient to drive traversers of the last-named type by high speed rope or square shaft, as applied to overhead travelling cranes, than to provide them with their own motive power. and this construction is usually less expensive.

TRAMCAR TRAVERSERS.—These have been built to work by electric or hand power and in some instances by either, at pleasure, but as tramway main stations are, as far as possible, laid out to dispense with cross traverse, a quite simple and inexpensive form of hand-power traverser usually answers every purpose.

TRAMCAR CRANES, see "Notes on Tramways.

ELECTRIC CRANES.

Fig. 5032.

The advantages of electric transmission of power, referred to elsewhere, are nowhere more prominent than in its application to cranes.

These advantages may be summarised as follows :

1. That although always available for service, no power is exerted or attention required when the Cranes are not usefully employed.
2. That the power consumed is more closely in proportion with the work performed than any other system.
3. That power is carried in any direction and to any distance, at less cost, and with far less loss than by any other system of transmission.
4. That the number of machines can be increased with little or no interference with existing operations.
5. That it is entirely unaffected by heat or cold.
6. That it is compact, easily handled, and easily adapted for working at any desired speed.
7. That with little or no increase in generating power, current can often be utilised for crane service when not required for electric lighting.

PORTABLE ELECTRIC CRANES of the type Fig. 5032 are built of all powers, and with the same facilities as regards length of jib, variation of radius and locomotive appliances, if these should be required, as the steam cranes referred to in this volume and in Section II., the crane now illustrated being provided with all these appliances.

The current is collected in the ordinary manner, as shown in the engraving, or from a cable laid in a conduit as indicated in Fig. 5040.

Stability and facilities for driving and supervision.—The horizontal arrangement provides for these far more completely than can be attained by any other construction.

FIXED ELECTRIC CRANES.—The general construction is similar to that illustrated in Fig. 5032, but the revolving superstructure is mounted on a strong base plate for securing to concrete or other foundation, instead of on the travelling under-carriage shown in the engraving.

ELECTRIC GANTRY CRANES, portable or fixed.—The crane, as last described, is carried on a gantry of the height and span required and usually constructed as represented by Figs. 5008 or 5010.

Information required for estimating the cost of jib cranes.

Type of crane required.

Weight of maximum and of average working load.

Radius of jib in both cases.

State height of jib, if necessary, and depth to lift (if any) below ground level.

If house (Fig. 5040) or canopy (Fig. 5039) required, state which.

For portable cranes. State gauge of rails. Is travelling motion required?

For gantry cranes. State clear span and height required.

Voltage of current available (if any).

ELECTRIC OVERHEAD TRAVELLING CRANES—Exceptional conditions, of course, require exceptional design; but Fig. 5033 illustrates a crane of ten tons power, and is typical of all powers and spans as generally constructed.

Machinery.—Whether all motions shall be transmitted from a single electric motor, or one shall be provided for each operation, are questions for the purchaser to decide; but the results obtained from careful tests of cranes with single and with multiple motors are unquestionably in favour of the latter, and for this reason the multiple motor crane has been selected for illustration.

A separate motor is provided respectively for lifting the load, traversing from side to side and for travelling longitudinally; and these operations, separately or in any combination, are controlled from the suspended platform from which an unimpeded view of all operations is obtained. The appliances for this purpose can, however, be on the travelling crab itself, if desired, but the arrangement indicated in the engraving is usually preferred.

The current is collected from a cable carried along one side of the building, or in other convenient position, and is transmitted to the motors by copper conductors supported from the traveller girders.

Economies effected. Some statistics on this subject will be found in Notes on "Economical results of electric transmission."

SPEEDS OF WORKING—The following table of speeds for the different motions of electric overhead travelling cranes, when working with maximum loads, are usually satisfactory in regard to the quantity of work performed, as well as in economy in first cost and in consumption of power. If, however, any of these speeds are found to be insufficient for the conditions to be fulfilled, it will scarcely be necessary to point out that any higher speeds desired are easily provided by increasing the proportions of parts and of motors, which of course, entails some increase in the cost of the machine and in the consumption of electric current.

APPROXIMATE WEIGHTS OF OVERHEAD CRANES.—The weights given in the table of three motor electric cranes of the respective powers and spans, ready for work, will be useful when arranging the sections of beams or girders for longitudinal track.

It should be borne in mind that the track beams must be capable of supporting the maximum load, plus half the weight of the traveller which may come on either end cradle.

CLEARANCE DIMENSIONS.—Unnecessary expense (and some inconvenience) is sometimes incurred by the clear height above longitudinal rails, and the space between them and the walls or columns being insufficient for cranes of the standard dimensions; the clearances required will be found in the following tables.

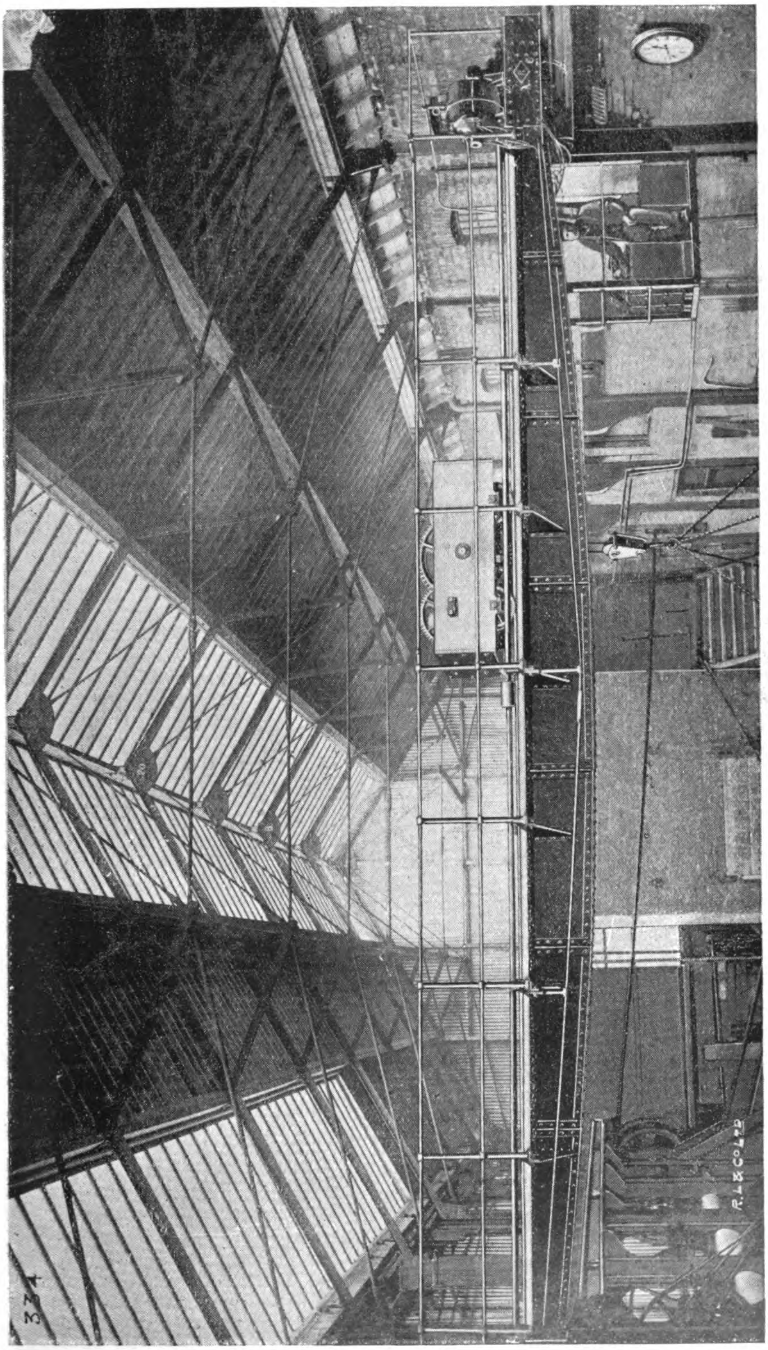


Fig. 5033.

STANDARD SPEEDS, DIMENSIONS AND WEIGHTS OF ELECTRIC OVERHEAD TRAVELLING CRANES.

Working load ... ... tons	3	5	10	15	20
Span (centres of longitudinal rails) ... feet	40	40	40	40	40
Approximate weight of crane .. ... tons	8	10	13	17	20
*Speed of lifting ... ... feet per minute	10	7½	5	4	4
* ,, cross traverse ... ,,	60	60	60	60	60
* ,, longitudinal travel ... ... feet	150	150	150	120	100
Clear height required above top of longitudinal rails ... ... feet	5	5¼	6¼	6½	7
Clearance between rail and wall or column, inches	8	8	9	9	10
Height of lift ... . feet	20	20	20	20	20
Working load ... ... tons	25	30	35	40	50
Span (centres of longitudinal rails ... ... feet	40	40	40	40	40
Approximate weight of crane ... ... tons	24	28	32	36	45
*Speed of lifting ... ...feet per minute	3½	3	3	3	3
* ,, cross traverse ... .. ,,	60	50	50	50	40
* ,, longitudinal travel ... .,	100	100	80	80	80
Clear height required above top of longitudinal rails ... ... feet	7½	7½	8	8	8½
Clearance between rail and wall or column ...inches	10	10	10	12	12
Height of lift ... ... feet	20	20	20	20	20

* See the foregoing remarks on "**Speeds of working.**"

SPAN.—About 40 feet being an economical span as regards cost of roof, and convenient for many purposes, this span and a lift of 20 feet have been adopted as the units for calculating the weights of cranes, but these dimensions are, of course, varied to any extent desired.

INFORMATION REQUIRED:—

Weight of maximum and of usual load.
Span centre to centre of longitudinal rails and side clearances, or :
Length over all between walls or columns.
Clear height available above longitudinal rails.
Length of longitudinal travel.
Total height of lift.
Divergence required (if any) from standard speeds.
Voltage of available current (if any)—kind of work to be performed.

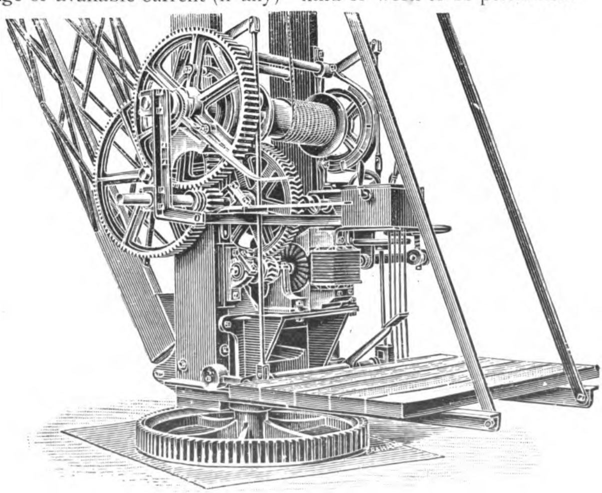


Fig. 5034.

ELECTRIC SAFETY DERRICK CRANE.—Fig. 5034 shows the lower portion of a derrick crane of ten tons power with electric appliances which transmit power for lifting, slewing and derricking in the same manner as a steam crane, so that a driver who has been accustomed to the latter has little to learn when transferred to an electric crane. The mast, back ties and sleepers are arranged as represented by Fig. 5084, and the cranes are as easily dismantled and re-erected as the ordinary hand-power crane.

ELECTRIC GOLIATH AND TITAN CRANES are built of all powers and capacities, but the structural features so closely resemble those described at pages 21 to 25 (excepting that electric is substituted for steam power) that it will be unnecessary to illustrate or describe them in detail.

ELECTRIC WALL AND WAREHOUSE CRANES for new and large installations must frequently be specially designed, especially those in railway goods sheds, but many electric winches similar to Fig. 5035, have been substituted, with great advantage, for the hand-power gear hitherto employed in existing cranes.

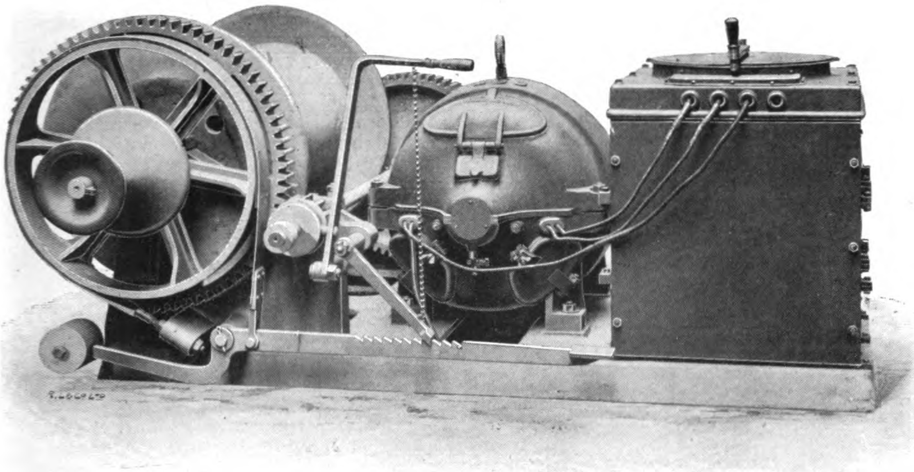


Fig. 5035.

ELECTRIC WINCHES.—Fig. 5035 is an example of a self-contained winch with a lifting speed of about 200 feet per minute and base plate for bolting to deck, floor, or masonry foundation, and with such modifications as circumstances require, a similar arrangement is adopted for winches of all powers and speeds, for a great variety of purposes from handling ordinary goods to mine haulage. The winch illustrated is fitted with spur gear throughout and the load can be lowered by a powerful pedal brake, or by power as desired.

ELECTRIC CAPSTANS.—The arrangement is similar to that adopted for hydraulic capstans of the familiar type, and consists of a box formed of cast iron flanged plates in which the electric motor, the bearings for the capstan spindle and gear for driving it are fixed and enclosed.

The motor is reversible and is started or stopped by a switch actuated by pedal or lever, as may be convenient, and the needful facilities are afforded for access to the working parts for supervision and maintenance.

COST OF ELECTRIC POWER FOR LIFTS, CRANES, Etc.—It is estimated that if current cost three pence per Board of Trade Unit, a direct coupled passenger lift carrying five persons, or a crane or other machine performing equivalent duty, will make 100 "trips" or operations at a cost of six pence for current.

With current at two pence per unit the cost of the 100 operations is about four pence, but with an efficient gas power installation the cost is considerably less than one penny per unit which, on the above-named basis, brings the cost of the 100 operations to less than two pence.

CRANES AND CRANEAGE.

The work performed by cranes varies so widely, that the examples selected for illustration and description must be limited to types in general use and if more detailed information is desired, it will probably be found in Section II. of this series, but special machinery naturally requires special consideration.

Merits of systems.—It is now generally recognised that initial cost of plant is a consideration of far less importance than complete adaptation to the conditions to be fulfilled, and the writer's experience indicates that, in the absence of competent advice with reference to the system to be adopted, the following notes on the comparative cost, efficiency, working expenses, etc. of the systems respectively mentioned, will be acceptable to many who have not had opportunities of studying these questions in detail.

HAND POWER CRANES.—Valuable as these are for occasional use, they will probable be found to be too slow, and too costly in manual labour to deal satisfactorily with large quantities of materials, and for this reason, they are not referred to in detail in these notes, information relating to them will however be found in the above named volume, as well as in trade catalogues. The subject is also referred to at pages 109 to 111.

STEAM CRANES.—Various forms of steam cranes referred to elsewhere, and in much detail in the above-named Section II. are so well known that it will only be necessary to summarise their principal features. These are: That each machine is complete in itself, and is slightly (if at all) affected by climatic conditions. That the power consumed is in direct proportion with the work performed, and that the number of machines can be increased without interfering with existing operations, the portable cranes being available for service over any railway track, and even for hauling rolling stock. These features, and the comparatively low cost of steam cranes, are important advantages, but other types are preferable under some conditions.

HYDRAULIC CRANES.—The direct acting pumps which generate hydraulic pressure by lineal motion throughout, run at comparatively slow speed, are extremely simple in construction, and cost little for maintenance. The efficiency of the hydraulic system is referred to later on.

ELECTRIC CRANES.—The loss of power in converting the rotary motion of the electric motor into linear motion for lifting the load, is less than that consumed in overhauling the lifting ram chains of hydraulic cranes, and the extreme flexibility of electric transmission, together with its high average efficiency, are strong recommendations to its use in connection with cranes, capstans, and other labour and time saving machines.

COST OF INSTALLATIONS.—The total cost of fairly large installations of equal capacity is usually, approximately as follows: The cost of steam cranes is the lowest. That for hydraulic and electric cranes, including machinery, power mains, buildings, etc. is higher and usually about equal, but if—as in the case mentioned at page 66—power is available from installations for lighting or power supply, the balance is distinctly in favour of the electric system, In this connection it may be well to point out that generally speaking, the electric light is used only about one-third or one-fourth the number of working hours of cranes, the periods overlapping to the minimum extent, and that the power required to work the cranes is relatively so small, that the margin provided for emergencies, repairs, etc. frequently suffices (without increase in generating power) for working the cranes. This, of course, does not apply to large installations for docks, harbours, etc.

Details of cost.—Hydraulic cranes cost less than electric cranes of equal capacity, but the engines, boilers, accumulators, pressure and return mains and buildings for the hydraulic system, cost more than the generating power, conductors and buildings required for an electric installation, inclusive, in both cases, of erection, laying mains, etc.

Cost of transport.—If weight and measurement have to be considered, the cost of transport will be much higher for hydraulic than for electric plant of equal capacity.

SPEEDS OF WORKING.—It is commonly held that the higher the speeds of the lifting and other operations, the larger will be the quantity of work performed by the crane, but experience shows that the time occupied in preparing loads for the crane, and releasing them, is the true measure of useful effect.

Cranes rarely work two-thirds of their time and if some such margin is provided, all beyond that usually entails waste of power and of capital outlay on generators and motors.

EFFICIENCY OF HYDRAULIC AND ELECTRIC CRANES.—The useful effect obtained from well designed plant is about 60 per cent. of the power delivered to the crane, when either system is working at its full capacity, but as the ratio of useful effect yielded by hydraulic pressure diminishes, in the proportion in which the load is less than the maximum, whilst that of the electric crane remains at about 60 per cent. when loads vary as much as 60 per cent. below the maximum for which the crane was designed, it follows that, if, as is almost invariably the case, the average load is very far below the maximum, considerably more power will be expended by the hydraulic than by the electric system for equal tonnage in varying loads.

CONSUMPTION OF POWER.—As indicated in the foregoing paragraph, this varies with the nature and frequency of operations, but taking a consumption of 1000 gallons of water per hour, at a pressure of 750-lbs. per square inch. as a convenient unit, the average cost of working the hydraulic crane will be about double that of an electric crane of equal power which consumes 3·5 to 5·00 Board of Trade units per hour, supplied at usual rates.

WEAR AND TEAR.—With the driving and attention usually obtainable, this is quite an unimportant item, the cost for either system being amply covered by an appropriation of 5 per cent. per annum, the last practice being adopted for electric cranes.

Summary.—From the foregoing it will be seen that whether the lifting machinery shall be driven by steam, electric, hydraulic or manual power, is purely a matter of convenience, but the safety, cleanliness and extreme flexibility of electric transmission will probably lead to its almost universal adoption where a number of cranes, or other lifting appliances are to be employed.

CRANES FOR DOCK, RAILWAY AND GENERAL SERVICE.—The great importance of rapid despatch has been forcibly pointed out in a paper by Mr. Hunter, M.Inst. C.E. the Chief Engineer of the Manchester Ship Canal, read before the Institution of Civil Engineers.

After expressing the opinion that complete efficiency is a far more important consideration than the cost of the plant, and that the interests of both dock and ship owners are best served by quick and economical despatch, Mr. Hunter directs attention to the fact that the saving of one day in the despatch of steamers such as those now engaged in the Atlantic service, is equivalent to a gain to the owners of at least £100, or (say) £2400 for the usual twelve round trips per annum, probably more than 2½ per cent. on the cost of the steamer.

These considerations apply equally to railway service, because evidently all acceleration and economy in handling goods will proportionately increase the earning power of a given quantity of rolling stock and station accommodation, to the distinct advantage of both railway and customer.

Special designs are constantly being made to cope with local conditions and it may almost be said that, for working to best advantage, scarcely any two installations of moderate capacity, can be really identical, so that the examples referred to in this volume and in Section II. can only be regarded as representative and capable of many modifications and combinations which are neither illustrated nor described.

LOCOMOTIVE AND PORTABLE STEAM CRANES.—Fig. 5036 represents the crane selected by H.B.M. Commissioners for the Paris Universal Exhibition of 1900 for service during the installation of the exhibits, and Fig. 5037 those so largely employed for all purposes where a high speed of travelling is required with ordinary rolling stock.

Both the cranes are of the usual type and the appreciation of the Gold Medal, which was awarded to the constructors, is greatly enhanced by the remark made by M. Loubet, the President of the Republic, who said—after thanking the members of the Jury for their pains-taking impartiality: "Among so many meritorious productions, the Jury have only been able to select the most striking."

Power and construction.—The cranes illustrated are both of 5 tons power, but a reference to the engravings of cranes of other powers which appear in this volume and in Section II. (which treats exclusively of Hoisting Machinery) will show that a similar arrangement is adopted for cranes of all powers from 1 to 25 tons, or more, whether with appliances for travelling, and for altering the radius of jib by steam power, as illustrated, or only for lifting and rotating through a complete circle, which is often all that is necessary.

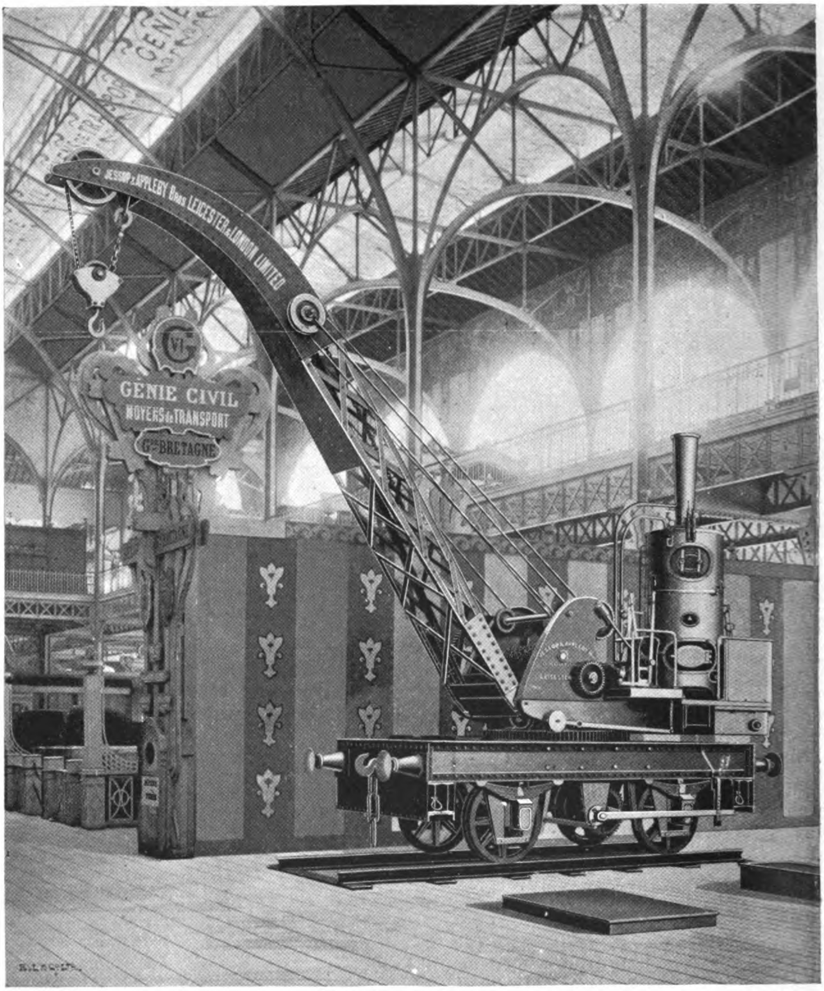


Fig. 5036.

There are several valuable features in these cranes not always found in others, amongst which may be mentioned :

The slewing path and anti-friction rollers adjustable for wear.

Superior facilities for supervision and maintenance.

Great stability, and all operations within sight of the driver.

Lifting and slewing in either direction without reversing the engines.

Gauge.—The cranes illustrated are adapted for the usual gauge—4-ft. 8½-in.—and if any other gauge is required the distance between the heads of rails should be specified.

The radius usually required is given in the following table. This is measured from the centre of the crane to the centre of the lifting chain when the jib is at an angle of about 45°. If any other radius is required it should be stated, together with the ordinary and maximum load to be dealt with at the radius desired.

LOCOMOTIVE CRANE WITH PERMANENT-WAY CARRIAGE, Fig. 5036.—Cranes of this type are referred to at pages 113 to 117, and that now illustrated is representative of the construction generally adopted for railway and long distance haulage.

Under carriage.—The frame is built of steel and fitted with steel-tyred wheels, springs, buffers, draw gear, brakes and all accessories requisite for hauling vehicles or travelling with rolling stock. The folding under-girders at each end of the carriage are drawn out and blocked to ensure stability when working on loose ground.

The superstructure is a massive casting which carries the engines and all working parts arranged horizontally, with the boiler, feed-water tank and coal bunk in the rear which provides useful counterweight and provides ample space for the driver.

The jib is of steel, lattice braced, and is curved to afford facility in handling large packages at close quarters.

Prices of cranes.—Drawings descriptions and prices of many sizes and combinations will be found in Section II. of this series, but the prices of cranes in general demand of the type now illustrated, with appliances for altering the radius of jib, and of travelling by steam power, all operations being controlled from the driver's platform, are approximately as follows :—

PRICES OF PERMANENT WAY STEAM CRANES, Fig. 5036.

Power of crane ... ... tons	5	7	10	15
Price of crane	£560	£625	£1000	£1200
Felting and lagging boiler	£14	£15	£18	£20
Set of rail clips	£5	£5	£5	£6
Tools and lock-up box	£5	£5	£5	£5

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

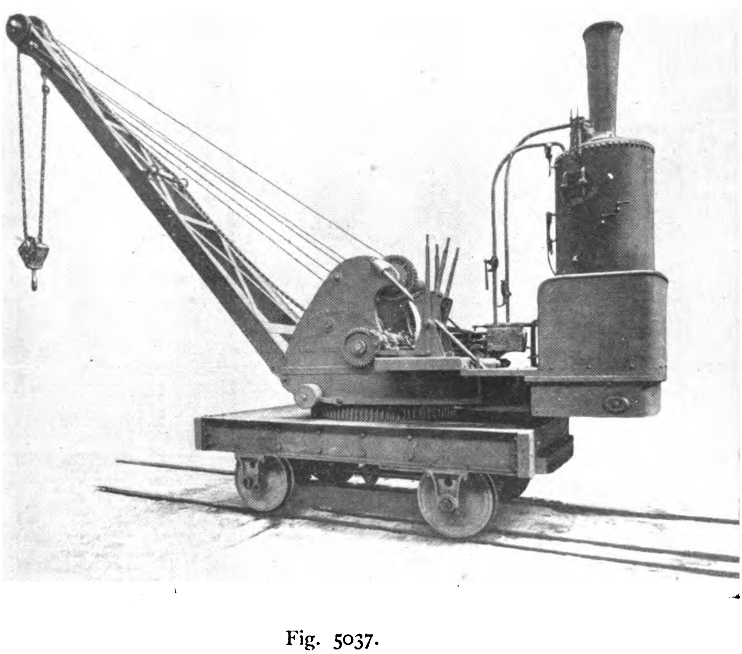


Fig. 5037.

PORTABLE STEAM CRANES.—The foregoing general description applies equally to the well-known type represented by Fig. 5037 excepting as regards the under-carriage which is adapted for moving comparatively short distances and occupying minimum space, as required in docks and many works of construction.

Proportions and combinations.—These are very diversified as regards the radius of jib, motions required and so forth, but the approximate cost of cranes of the powers and with the combinations generally required will be easily obtained from the following table.

Cranes exceeding 5 tons power have wrought iron under-carriage.

PRICES OF PORTABLE STEAM CRANES, Fig. 5037.

Power of crane	tons	1	2	3	5	7	10	12
Radius of jib	feet	11	15	16	16	16	16	16
		£	£	£	£	£	£	£
Price of crane to lift and slew ...	...	190	290	356	450	545	735	800
Extra for steam derrick motion ...	..	8	10	11	15	20	30	40
,, steam travelling ,, ...	..	15	20	22	25	30	40	45
,, curved steel jib	...	15	17	18	22	23	25	30
,, wrought iron carriage ...	...	10	11	12	...	...	...	...
,, if wheels steel tyred ...	...	10	10	10	10	15	20	25
,, sliding under-girders ...	..	...	...	12	13	14	15	18
,, set of rail clips	...	4	4	4	5	5	5	6
,, Felting and lagging boiler...	.	11	12	13	14	15	18	20
,, Galvanised iron house ...	..	10	15	16	20	23	25	25
,, Injector and fittings ...	...	6	6	7	7	7	8	8
,, Tools and tool box ...	...	4	4	4	4	5	5	5

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

CRANES FOR QUAY SERVICE employed in handling merchandise, coals, &c. must, however, frequently have jibs very much longer than those last mentioned.

The general arrangement is similar to that indicated in the engravings but the speeds of working are much higher, so that the greater strength and weight of the crane involve increased cost in proportion with the normal load, radius of jib and speed of lifting.

QUICK WORKING CRANES, of the kind last referred to, easily deal with 50 to 60 loads per hour, which, in ordinary cargo, is much more than can usually be stowed on board, or in wagon or warehouse.

The conditions vary so widely that cranes for these purposes should be specially designed to suit the maximum and ordinary load, the height of lift, usual working radius and the number of operations to be performed per hour, all of which should be clearly defined.

In this connection it may be well to point out that speed is secured and capital outlay saved by having quick-working cranes equal to average maximum load. This rarely exceeds 1½ tons, and is often not more than about 10 cwt. a few cranes of greater power being provided for the (exceptionally) heavier loads.

It will be evident that high speeds cannot conveniently and economically combine with great lifting power; also that uniformity in design and arrangement—as far as attainable—goes far towards ensuring facilities both in driving and maintenance.

Working expenses.—In this and most European countries, the working expenses, including craneman's wages, fuel, oil, &c. rarely exceeds 10/- to 12/- per day, so that if only 30 operations per hour are made with average loads of 1 ton, the cost is less than one halfpenny per ton for lifting, lowering, and depositing the load at any point within the radius of the circle—frequently 30 feet, or more—described by the jib.

Handling coal, coke, minerals, &c.—If the cranes are used in connection with grab buckets, as indicated in Fig. 5040, the above-named output may be very largely exceeded, and the cost per ton proportionately reduced.

JETTY CRANES ON FIXED GANTRIES.—The large installation now briefly referred to, for which the writer is largely responsible, fulfils conditions not often met with, but may be worthy of mention on account of its novelty and success.

Conditions fulfilled.—Each jetty is provided with four cranes which are available for service at any point on either side of the jetty, for transferring merchandise between steamer, railway wagon or go-down, without re-handling or interfering with circulation on the jetty.

Construction of jetty.—These are formed of massive concrete walls, a portion of the space between them being utilised as cold storage vaults, with go-downs above for warehousing produce, merchandise, &c.

Two lines of railway on each side of these galvanized iron go-downs connect the jetty with the main line, the crane gantries being outside the railway lines.

Crane installation.—This consists of steam cranes of 5 tons power, with quick speeds for loads up to 2½ tons. The radius of the jibs is about 30 feet and the motions, are as described at page 61.

Each crane is mounted on a pair of transverse girders with end carriages and wheels which run on wrought iron longitudinal girders; these are supported on columns fixed near to the copings, and the height admits of the cranes passing over the roofs of the go-downs. Portions of these roofs are removable, so that the cranes completely fulfil all essential conditions.

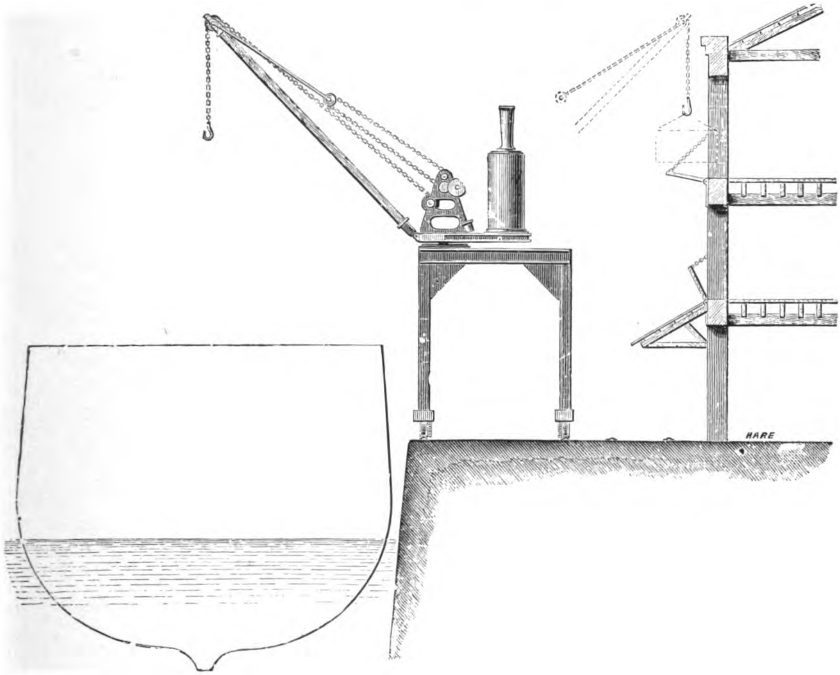


Fig. 5038.

PORTABLE STEAM GANTRY CRANES.—The arrangement indicated in the diagram engraving Fig. 5038 has been successfully used for transferring cargo to or from steamer, quay or warehouse in a tidal harbour and in all states of the tide.

The portable gantry, equipped with a crane of the power and radius required, admits of rolling stock passing beneath it and can be moved along the quay, two or more cranes being concentrated on vessels requiring exceptionally quick despatch.

Work performed.—A steamer carrying 5,000 tons of hematite ore has come in and been discharged and left the dock by the next tide. This work was done by two cranes at the main hatch and one at each hatch, fore and aft, or four cranes in all; relatively good results are obtained in handling ordinary merchandise.

GANTRY CRANES AND OTHER APPLIANCES FOR COALING are referred to at page 71.

ELECTRIC CRANES of the usual types are illustrated and described at pages 52, 65, etc. but the foregoing remarks apply equally to similar machinery driven by electric power.

CONVEYORS OR TRANSPORTERS perform some of the same functions as jib or overhead travelling cranes, details of which will be found at pages 77 to 80.

HYDRAULIC CRANES.—So many docks, goods stations, etc. are equipped with hydraulic machinery that there will always be a demand for it for extensions and renewals, but as details relating to hydraulic cranes are given in Section II. (pages 59 to 68, etc.) it will be unnecessary to repeat them here. See also page 4.

But, as pointed out elsewhere in this volume, probably electric transmission will, in future, largely supersede the hydraulic system in large installations, most of the small ones being provided with electric plant equal to supplying both light and power, or with steam cranes, as at present.

HANDLING AND STORING COAL, MINERALS, ETC.

The leading features of plant for these purposes are referred to in the following pages, for the most part, without details of proportions, cost and so forth, which cannot be determined until all the circumstances have been considered.

Widely as the arrangement and construction of appliances may differ, the amount expended on plant is comparatively unimportant, provided that it is in proper relation with the volume of work, and that the undernamed results are obtained.

Speed of working, minimum working expenses, minimum breakage.—The speed of working so largely affects the earnings of both vessels and rolling stock that it is a matter of first importance.

RAILWAY TRANSIT.—To ensure complete adaptation of coal tips or coaling cranes, drawings should be furnished showing the dimensions and wheel base of the largest and smallest wagons to be handled, and information as to their cubical capacity, total weight (full and empty) and the nature of materials to be dealt with, or their specific gravity.

IMPORT AND EXPORT.—These terms are used as conveniently representing the operations of discharging and loading, and unless cranes or conveyors are employed (which are, of course equally adapted for both purposes) it rarely happens that plant for one of these operations is really quite satisfactory for the other.

PLANT FOR IMPORT.—Examples are given in Fig. 5039 and Fig. 5040 respectively of steam and electric cranes, the latter with grab bucket which is controlled by the crane man in filling and emptying automatically. Attention is also directed to the appliances for weighing and distributing into bins at different elevations and angles, as described at page 67.

Working expenses.—One steam or electric crane, with grab skip as illustrated, will load or discharge 600 to 700 tons of coal in 10 hours, at a cost not exceeding 1d. per ton (and frequently very much less) including all expenses and labour incidental to transfer from ship to wagon or lighter, or the reverse operation, so that one man with crane and grab bucket will handle more coal or coke, in a given time, than eight men with shovel or fork, and make far less breeze.

Millions of tons of coal which must be handled with the least possible breakage and at the lowest cost, are annually dealt with by these appliances.

CONVEYORS.—Reference to pages 77 to 80 will show that fixed or portable plant of this kind can be arranged to convey coal or ore through considerable distances, very quickly and at remarkably low cost; it can, moreover, be adapted for either import or export.

SUPPLYING GAS WORKS, BOILER HOUSES, &c,—It will be obvious that plant of the kind illustrated by Fig. 5042 or of that last referred to, whether worked by steam or electric power, will weigh and deliver fuel to store from which small trucks are filled, or direct to the stoker hoppers.

Similar arrangements are also adopted for filling carts or sacks for local distribution.

Fig. 5039.

COAL DISCHARGING CRANE AND SKIP.—The engraving, Fig. 5039, clearly shews the arrangement of plant and it will only be necessary to say that the steam crane travels along the track on the Gas Works property, the jib being long enough to reach over the fence and towing path, without interfering with "rights of way," and deposits the coal over a very large area of storage.

The crane has steam travelling and steam derrick motions so that the jib is readily adjusted to reach any part of the coal barge. Flexible steel wire rope is used for lifting and derricking and—as will be seen—a galvanised iron canopy with sliding curtains protects the driver in hot or wet weather.

The skips, of one cubic yard capacity, are of the turn-over type, illustrated on a larger scale by Fig. 5056, and the dumping block, controlled by the crane driver, admits of the skip being emptied at any point desired.

This plant completely fulfils the conditions for which it was designed.

ELECTRIC CRANE AND GRAB BUCKET.—Plant for similar service worked by electric motor, but a grab bucket taking the place of the turn-over skip is illustrated by Fig. 5040; either crane can, however, be used either with grab or turn-over skip.

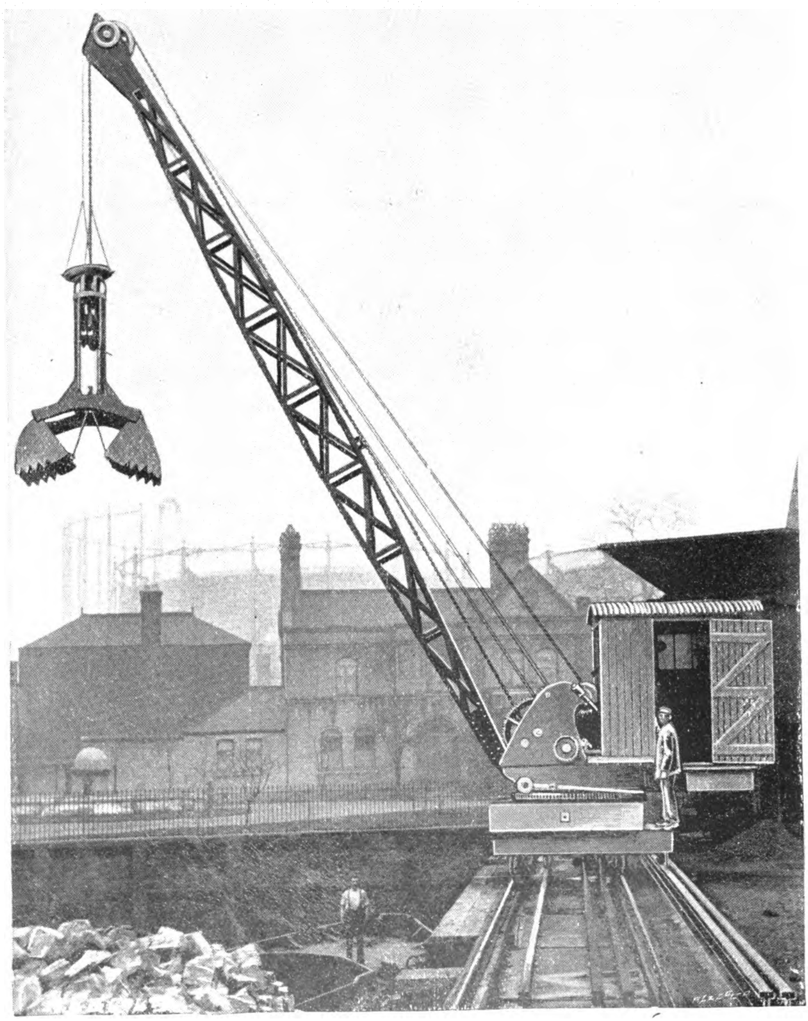


Fig. 5040.

ELECTRIC COAL UNLOADING AND CONVEYING PLANT.—The installation now referred to for unloading barges laying alongside wharf, and finally conveying the coal to the stores, without recourse to manual labour, has been selected by "The Engineer" as an example of successful plant for this purpose, and the following engravings and descriptive matter are abstracted from the pages of that valuable publication.

Attention is specially directed to the ample space provided for the driver, as indicated in the following diagram; also to the convenient arrangement of controlling levers, and to the very direct and positive transmission of power.

The arrangements of parts is similar to that mentioned in previous pages, and indicated in the diagram Fig. 5041, but the motor and some of the gear had to be adapted to suit the current at the Company's disposal. The grab skip is of the well-known type worked by single chain, with appliances for filling and emptying automatically.

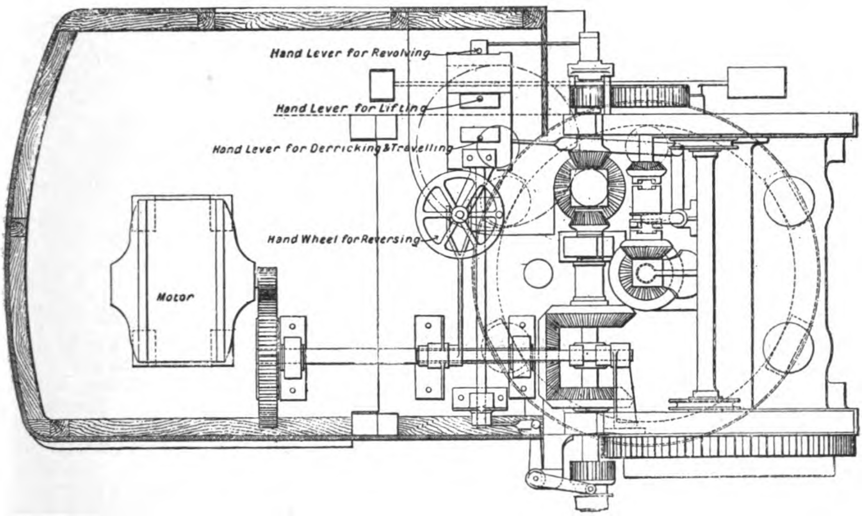


Fig. 5041.

Mode of working.—The coal taken up by the self-filling skip is delivered into the hopper which is seen beyond the crane, and carried thence by the elevator and conveyor into store, as shown in the diagram engraving Fig. 5042. "*The Engineer*," writes as follows:

"**The Travelling Electric Crane** which runs along the coal wharf is of the jib type, and constructed by Jessop & Appleby Bros. Limited, Leicester, is mounted on a four-wheeled carriage arraanged for 4 feet 8½ inch gauge of rails. The carriage centre is a massive casting fitted with steel pivot and roller path.

The travelling motion is conveyed through the pivot pin by a strong steel shaft, and both axles are driven by one shaft through cast steel gearing. There is only one motor on the crane, and it works all the motions. This motor, which at full load runs at 925 revolutions per minute, works through reduction gearing on to a counter-shaft, which in its turn drives the winding, slewing, travelling, and jib-adjusting motions. The various motions are controlled by means of a reversible friction clutch.

The motor only runs in one direction. It is of the two-phase brushless type, and is of 20-horse-power. The working pressure is 200 volts, and the periodicity 50.

The lifting gear is of the spur type, and lowering is controlled by a strap brake and foot lever. The slewing is fitted with an additional reversing clutch, in order that the motion may be adjusted either way while any other motion is being carried out. The jib adjustment is brought about by power through the medium of worm gearing, and is self-locking.

The crane duty is the lifting of 40 tons of coal per hour from the barges and delivering them into a hopper which is 15 feet above rail level. The greatest radius of the jib is 30 feet. It is provided with a Hone grab of over half a ton capacity. . . .

The weighing machine into which this crane delivers is capable of dealing with 40 tons of coal an hour. It is supported on a structure of H iron, and consists as follows:—A hopper, with an inside measurement of 6 feet by 6 feet is placed above the weighing machine, which when the coal has been weighed, delivers it into a second hopper, which terminates in an automatic feeder communicating with the receiver at the lower end of a 24 inch elevator. The feeder is driven from the bottom shaft of the elevator by means of a sprocket wheel and chain. This wheel also works the agitator of the weighing machine. The feeder is introduced for the purpose of regularly feeding the elevating and conveying plant, which we are about to describe, so that there may be no possibility of choking at the boot, the feed being so regulated that when the buckets of the elevator come round they may only take up their proper quantity of coal.

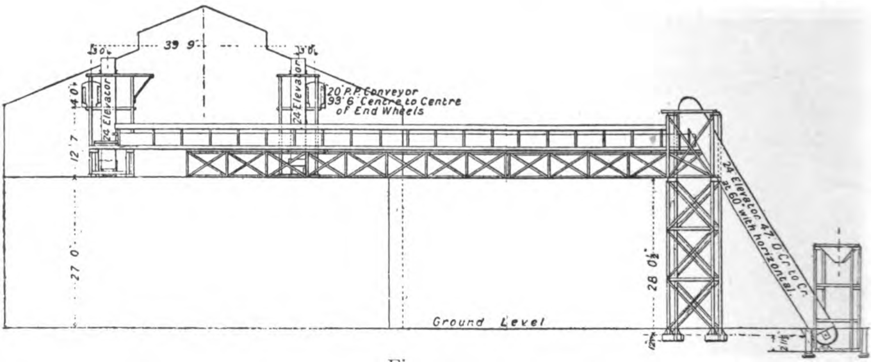


Fig. 5042.

The elevator is a chain of buckets running in a casing. It is 47 feet from centre to centre of its driving shafts, and is placed at an angle of 60 deg. with the horizontal. The conveyor is driven by means of a 5-brake horse power motor fixed at its upper end. The motion is transmitted through worm and worm wheel and spur gearing to the upper driving shaft. The elevator delivers the coal on to a 20-in. push plate conveyor, working at about 33 feet above ground level, along a lattice girder structure carried on H iron uprights made rigid by cross and diagonal stays. The 20-in. push plate is 179-ft. 6-in. from centre to centre of the sprocket wheels driving it, and at the end farthest away from the elevator it is provided with two outlets or traps by which the coal may be delivered into either of two small elevators connecting with either side of the coal store.

These two conveyors are 21-ft. and 19-ft. from centre to centre respectively, and are similar, save in height, to the elevator already described. They deliver through a shoot into either of two push-plate conveyors which run down the coal store, being 20-in. conveyors, exactly similar to that on the two lattice girders. These are 73-ft. from centre to centre. As the coal is taken along the troughs of these it can be dropped into any of the bunkers it passes, through holes provided with doors, which can be opened and closed at will.

Our illustration (Fig. 5042), shows a diagrammatic view of the whole apparatus, and will give an excellent idea of how the plant works.

In addition to the 5-brake horse power motor already mentioned as driving the main elevator, there are a 20-brake horse power motor for driving the long push plate and the two smaller elevators, and two 7½ horse power motors for driving the two push plates in the coal stores. These motors, which together with the 20 horse power crane motor, are all of the Westinghouse two-phase type, work at 200 volts and 50 periods. The main shaft of the large push plate and two smaller elevators, is geared down by means of worm and spur gearing, and there are also provided a pair of mitre bevel wheels and counter-shaft on which is keyed a sprocket wheel and chain gearing for driving the two smaller elevator counter-shafts. On these shafts there are mounted pinions provided with claw clutches, so that either elevator may be used as may be desired. The gearing of the 7½ horse power motors for the smaller push plates is of the same character—worm and spur gearing."

The current for the travelling crane is picked up by means of shoes from three rails, and, so as to allow for the revolution of the crane, three contact rings are provided in the lower part of the crane, arranged concentrically round the central pivot, and specially designed rubbing contacts take the current from these.

ELECTRIC COALING CRANES of other types are referred to at page 73.

COALING TOWER WITH BOOM AND GRAB BUCKET.—This arrangement is not illustrated, but being an adaptation of the conveyor system referred to elsewhere, the following description will probably suffice.

The plant consists of a stationary or travelling tower with boom (usually about 60-ft. long to reach the centre of the largest vessel) and appliances for automatically filling and emptying the grab bucket, and for lifting and traversing it from hatchway to wagon or bin on quay.

Tower and boom.—These are built of iron or timber and are fixed or portable as the service requires. The boom is fitted with a travelling jenny, sheaves, steel-wire rope and other accessories for carrying the grab bucket, and for lowering it out at any point in the length of traverse; also for raising the boom to clear masts, etc. when out of use.

Grab bucket.—This is built of steel to hold one to two tons of coal and is lowered into the hold when open (as indicated in Fig. 5040) where it is filled automatically by winding in the lifting rope.

Steam or electric machinery.—This consists of a hoisting engine or electric motor with two drums to carry the ropes for lifting and opening and closing the buckets, another being provided for traversing the jenny.

The boiler may be fixed in the tower or at a distance from it, as may be convenient.

Work performed.—One complete operation—lowering the bucket, filling, lifting, traversing and emptying it—can be made in 15 seconds, but the quantity discharged in a given time is really governed by the speed of trimming forward in the hold and of manipulating the railway wagons. When working well, as much as 1200 tons has been discharged and delivered into trucks in eleven hours, but the average is about 80 to 100 tons per hour for plant of the usual capacity.

Working expenses.—Two men are required to manipulate the machinery and—including the hands in the hold trimming towards the hatchway—the cost of unloading and delivery into truck on quay does not exceed about one halfpenny per ton.

The cost of a portable tower, as described and complete with machinery and grab bucket, is about ... ... £2000.

The cost of machinery only, ready for erection on a timber structure provided by the purchaser, is about ... ... £1100.

FIXED COALING TOWERS naturally cost rather less and may, in some cases, be quite as convenient as portable towers, but mobility is often of great advantage.

COAL AND ORE CONVEYORS are referred to at some length at pages 77 to 88, but attention may be directed to their capacity for quickly and cheaply transferring from vessel to railway wagon or store, or the reverse operation, without re-handling.

The buckets employed can be emptied automatically at either end, or at any desired point in the length of traverse; the great advantage of this is that the breakage of coal is almost nil.

Appliances for hauling wagons are usually provided with these installations to obtain the full extent of economy in time and labour.

PLANT FOR EXPORT.—Where the natural levels are favourable and the necessary area is available, a system of gravitation of the "Staithes" type, formerly so common in the North of England, is economical and efficient, but in the absence of the above named conditions, ample experience shows that one or other of the mechanical arrangements about to be referred to will be found to be in every sense satisfactory.

Mechanical systems.—Excepting those mentioned under the heading "plant for import" the purely mechanical appliances for loading vessels with coal or ore, direct from railway wagons, may be divided into "coal tips' and "coaling cranes."

All experience is in favour of the former if the current traffic will keep the plant fairly well employed, but if that is not the case, and crane power is required for other service, the systems indicated in Figs. 5039 and 5040 are worthy of careful consideration.

The advantage in both cases, so far as rolling stock is concerned, is that only the ordinary open truck with end door or flap is required, this type being certainly far cheaper in first cost, and in maintenance, than the hopper wagons which are necessary for some of the other systems of discharge.

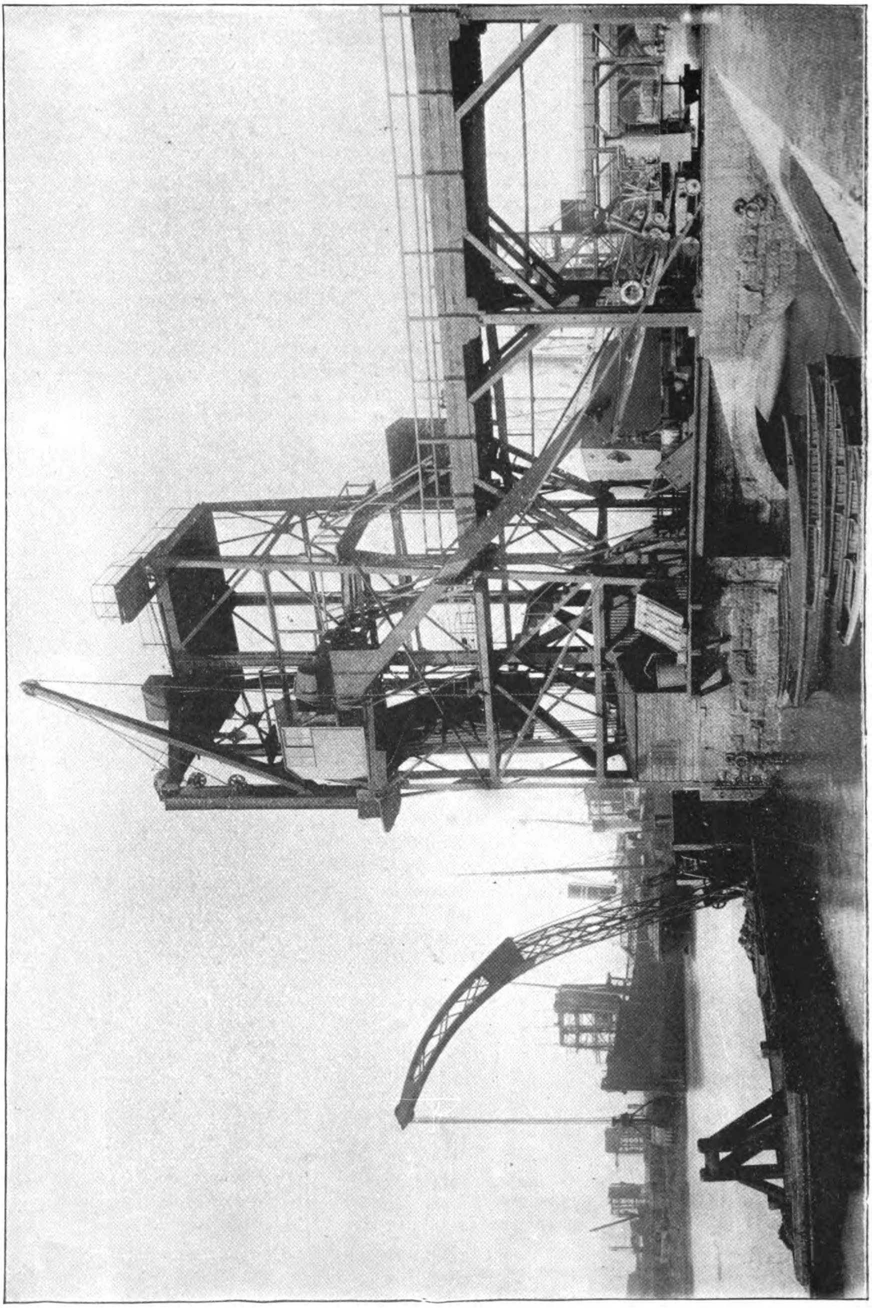


Fig. 5043.

HYDRAULIC COAL TIPS.—Fig. 5043 is re-produced from a photograph representing a tip of the well-known type, with the shoot triced up to clear vessels when being berthed, and some accessory plant which will be referred to later on.

The Tower is constructed in the usual manner, with deep water in front of the massive masonry foundations, and it is difficult to conceive more perfect and labour-saving arrangements for coaling than those now referred to.

Approaches to tips.—The trucks carrying 7 to 10-tons of coal are brought to the tip by main lines of railway which run parallel, or nearly so, with the dock wall, and after being weighed, are swung on a turntable into position for hauling on to the tip platform, hydraulic capstans being provided for both swinging and hauling.

Platform and shoots.—The rising platform, and the shoots, are arranged to admit of the truck being tilted to discharge at any height or at any desired angle, with the two-fold object of saving in consumption of hydraulic power, and reducing the breakage of coal.

Swing jib crane.—A further and important aid in the direction last referred to is provided by the hydraulic swing jib crane which is carried on one corner of the tower and employed, principally, in lowering sufficient coal in skips to form a cone or cushion, before tipping commences.

Some notes relating to anti-breakage skips will be found at pages 74 and 76.

Drivers cabin.—All motions are controlled from a cabin on the side of the tower, from which each operation is clearly seen.

Speeds of working.—These are about the same as are mentioned further on, but the total quantity of coal delivered in a given time is, of course, proportionately less than when two or more tips can be concentrated on one vessel.

The power station is in a central position for transmitting power to the coal tips, cranes, capstans, dock gate machinery, etc. with which these docks are equipped.

The engines are of the usual direct acting type and these, as well as the accumulators are arranged to work in any combination, at least one set being usually in reserve.

SUBSIDIARY PLANT.—This comprises anti-breakage skips for use in connection with the hydraulic swing jib cranes and described above.

The locomotive steam crane with grab bucket is largely employed in raising coal and clearing the floor of dock around the tip, but this crane is specially built with lowering chimney and jib, and the boiler swings in very limited space in order to be available for general service in any part of the docks, without encroaching on current traffic.

The floating crane (in the foreground) is used for removing refuse matter in front of the quays and in all parts of the docks. This installation is referred to at page 156.

PORTABLE HYDRAULIC COAL TIPS.—The advantage of mobility is as great in coal tips as in many other kinds of lifting machinery, provided that the approach roads can be conveniently arranged.

Tower and machinery.—The structural and general mechanical arrangements are similar to those indicated in Fig. 5043, excepting that the portable tips are mounted in travelling wheels, and the connections between the pressure and return mains and the hydraulic rams are made by "walking pipes" which admit of a considerable range of motion for adjusting position, without disturbing the connections with the mains.

Work performed.—A wagon containing 10 tons of coal is lifted 45 feet, tipped, and returned empty at quay level in 30 seconds after it has been placed on the rising table, and by concentrating two or more tips at the respective hatchways, more than 2,300 tons of coal have been put on board in about $2\frac{1}{2}$ hours, so that if the tips are available, steamers coming in can rely on being loaded and out, on the same tide.

All operations are controlled from a cabin near to the top of the tower as represented in Fig. 5043.

Maintaining an even keel, to which some owners attach great importance, is easily attained under this system of loading, or by having a coaling crane of the type Fig. 5039 or 5044 on one or both sides of the tip.

Anti-breakage arrangements.—In addition to the hydraulic cranes and boxes previously referred to, the shoots are fitted with movable plates and wings, and appliances which afford a certain amount of radiation from the centre line of the tip.

INCLINE TIPS.—Another arrangement is an inclined plane extending from the main line to the level of the platform for tipping, the coal wagons being weighed at the bottom of the incline and hauled up by hydraulic or other power.

When the trimmers work well each tip discharges an average of about 250 tons per hour, four men (including the incline attendants) being employed.

ELEVATED COALING JETTIES.—Large quantities of coal, ore, &c. are rapidly and economically shipped in bulk from an elevated staging provided with shoots, adjustable as to height and angle, at the end or sides of the jetty.

An arrangement which can be adapted to suit many local conditions consists of a timber or iron staging, with decking wide enough for two or more trucks, and hoppers below them into which the coal is delivered from drop-bottom trucks.

The hoppers are kept full, and shoots with appliances for raising, lowering, and fixing them with suitable inclination conduct the coal to the hold of the vessel being loaded. The speed of delivery is controlled by doors in the hoppers which are manipulated from the platform.

SPECIAL ARRANGEMENTS.—The foregoing epitome is by no means a complete record of the methods which have been adopted with more or less success, but those not mentioned may be regarded as coming into the category indicated in the heading of this paragraph.

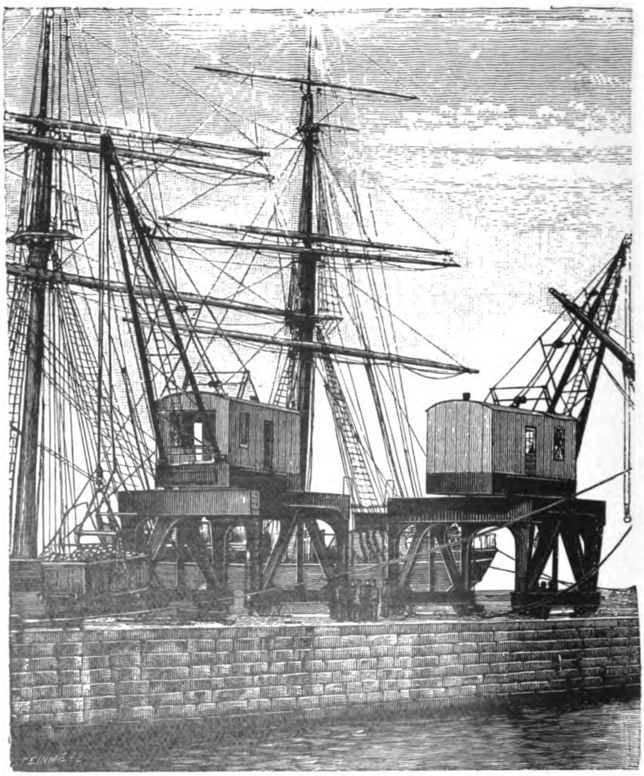


Fig. 5044.

CRANES FOR COALING IN BULK.—The engravings Figs. 5044 and 5045 represent extremely useful types of cranes which work with loads of 20 and 25 tons, and are mainly employed in shipping coal, but are also used for stepping masts, handling marine engines, boilers, locomotives or other heavy or bulky objects.

The same types are built of all powers and proportions, and—whether portable or fixed—are arranged for working by steam, electric, or hydraulic power.

Description of plant.—Steam or electric cranes are of the usual construction, excepting that, in addition to the lifting and slewing motions, there is a barrel for coiling the rope or chain for tipping the truck, as indicated in Fig. 5045, so soon as it is in position over the hatchway.

The lifting and tipping motions can be used in any combination, and these being under complete control, the coal or ore is discharged as quickly or as gently as desired.

Wagon and cradle.—The wagons are of the ordinary end opening type, and—in this case—carry net loads of 7 to 10 tons, but the plant is easily constructed to deal with trucks of larger capacity.

Bottom opening trucks can be used if desired, but the plain wagons with opening ends are less expensive in first cost and maintenance, and are quite as convenient.

The cradle is built of wrought iron, and provided with ramp rails and appliances for holding the wagons in position when being lifted or tipped. One cradle frequently suffices for each crane, but the speed of working can be greatly accelerated if there are two cradles for each crane, or not less than three for two cranes.

Capstans.—In the absence of a system of quay capstans for hauling wagons on and off the cradle, the crane itself is provided with capstans which are driven by power transmitted from the main engine or motor, or by a separate motor for each capstan, the latter being usually preferable.

Horses have been employed for this duty, but the result is scarcely satisfactory either as to speed or economy.

Speed of working.—From the foregoing it will be seen that the end door being opened when the wagon has been swung over the hatchway or shoot, the coal is rapidly discharged, the cradle being then replaced on the quay, ready for another operation.

Efficiency.—The Engineer-in-Chief reports of the plant illustrated by Fig. 5044, as follows:

"They (the cranes) have fulfilled all the requirements of my specification, and for smallness of cost, coupled with the facility for travelling from one end of the quay to the other without in any way interfering with the work on the quay, I am of opinion that they are the best design possible for localities where there is not only a large coal trade, but other trades. The cranes are used for loading machinery, masting vessels, etc. besides coal. The cranes have done 22 trucks per hour."

The number of trucks discharged in a given time depends largely on the dexterity of the quay hands, but as will be seen from the foregoing report each complete operation occupied less than three minutes.

The cost of a gantry crane, similar to that now described, is about ... £2250.

The cost of cradles necessarily varies in proportion with the dimensions of the wagon to be carried, the attachments necessary, etc. but it will probably be from £70 to £100 each.

LOCOMOTIVE STEAM CRANE OF 25 TONS POWER.—The capacity of the crane illustrated by Fig. 5045, and the mode of working being similar to that last described, it will only be necessary to refer to some details of construction.

Machinery.—Power for lifting, slewing and travelling is transmitted from the main engines, a small pair of engines being provided for tipping the truck when coaling, or for working the other motions and economising in consumption of steam when the crane is employed on light work.

The jib has a radius of 30-ft. and the curved form admits of a truck being raised to clear the side of the largest Atlantic liner when coaling, which could not be done with safety if the jib were of the ordinary straight type.

The under-carriage is built of wrought iron with a massive cast-iron centre piece and patent frictional roller-path which can be adjusted to maintain an even surface all round, as explained at page 60.

The travelling wheels have steel tyres and ample provision is made for stability when working under the conditions indicated in the engraving.

The cost of the crane fully equipped is about ... ... £2200.

The weight is about 90 tons.

The cost of the cradle varies from about £70 to £100. The price of that illustrated is £95.

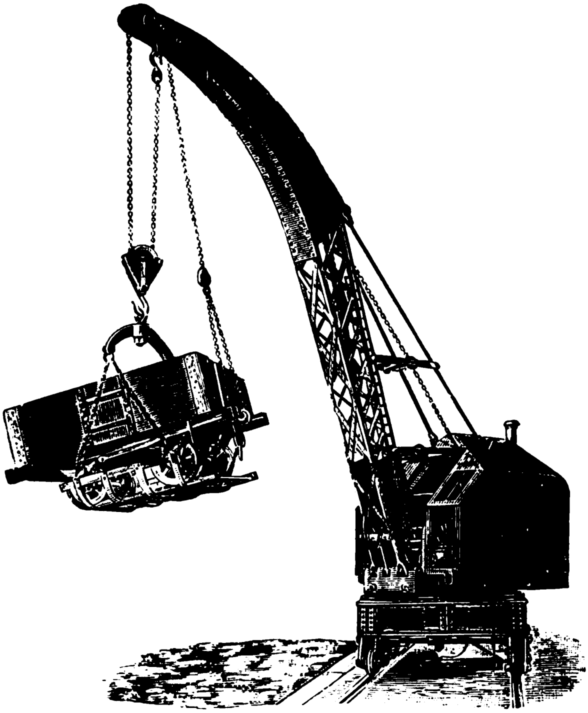


Fig. 5045.

FIXED STEAM COALING CRANES were largely used long before portable or ocomotive cranes of the power necessary for this purpose, were designed.

The general construction and mode of working are as last described, but a strong bed plate for fixing to concrete or other foundations is substituted for the under-carriage shown in Fig. 5045.

It is frequently desirable that fixed coaling cranes, whether worked by steam, electric or hydraulic power, should have appliances for altering the radius of the jib and for adjusting it centrally with the hatch or shoot, and thus reduce the cost of labour in trimming and, probably, some breakage of coal or coke.

The cost of fixed cranes with adjustable jib is rather less than that of portable cranes of equal power and proportions.

ELECTRIC COALING CRANES.—It will be evident that with very slight modification and scarcely any interference with the mode of working, any of the steam driven appliances referred to in the foregoing pages can be arranged to work by electric motor.

COALING SHIPS AT SEA.—Many attempts have been made to transfer coal from one vessel to another at sea, and important as the service is, especially in time of war, it cannot be truly said that any of the appliances hitherto devised have been more than very moderately successful, and it seems scarcely probable that the problem will be solved by private enterprise.

The most successful of these appliances has been a kind of wire rope conveyor with travelling carriage of the type Fig. 5055, which has conveyed 20 to 25 tons per hour from collier to battle-ship when steaming 5 to 6 knots per hour. But as continuity of work depends on the maintenance of proper distance between the ships (which is evidently impossible in rough weather) the coaling may have to be abandoned, probably at a time when it is most needed.

SHOOTS AND SKIPS.

The simplest form is, of course, the plain open trough built of wrought iron or steel adjustable in height and angle, with or without baffle plates which reduce the velocity of descent and the breakage of coal.

One or more stages of shoots of this kind are generally used in connection with coal-tips, and triced up as indicated in Fig. 5043 when out of use. This form of shoot answers admirably for transferring hard coal, ore, gravel, &c. but other appliances, similar to those about to be referred to, are sometimes indispensable for more friable materials.

ANTI-BREAKAGE SHOOTS.—An efficient form of shoot for this purpose consists of a circular or rectangular tube (usually the latter) the upper end of which is enlarged to the width of the shoot or wagon, and the lower end provided with doors at the bottom or sides which open outwards.

The lower length of the tube is telescopic, for adjustment as the hold is filled, and the bottom doors (controlled by the shoot man) are opened only when the coal or coke can roll or slide out with little or no fall.

Mode of working.—The coal is conducted to the shoot by the ordinary tip shoot, or from the wagon direct, as indicated in Fig. 5043, but appliances of this kind are capable of great modification, and one of them is mentioned further on under the heading "Anti-breakage Skips."

GRAB BUCKET SKIPS.—As these are illustrated and described at pages 156 to 159 it will only be necessary to refer to them here as anti-breakage skips which are capable of being used with any ordinary crane. The filling and emptying being automatic, the speed of working is high and the cost of labour (see page 4) remarkably low.

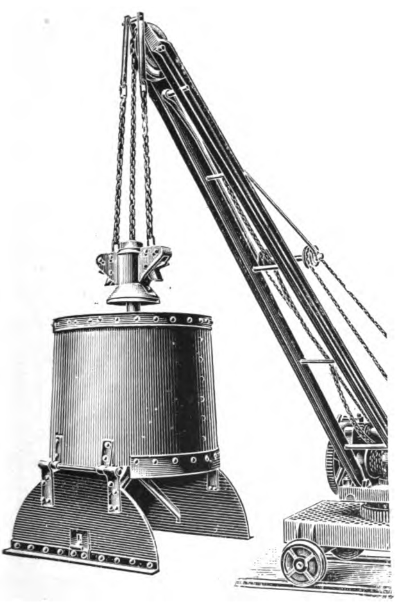


Fig. 5046.

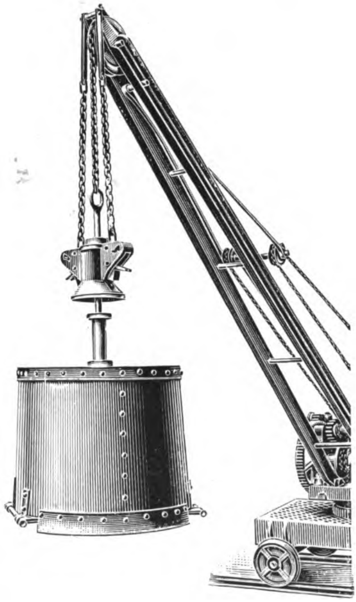


Fig. 5047.

DROP-BOTTOM (MURRAY) SKIPS.—Fig 5047 represents a cylindrical skip with bottom doors which open outward automatically when contact is made with the opening crown. Similar arrangements can be applied to the rectangular Murray Skip, illustrated by Fig. 5115.

The opening crown can be adjusted to come into operation at any height, and so discharge the materials with little or no fall, if so desired, and without loss of time; only one crown (or clip) is required for any number of skips.

The mode of working is extremely simple. The skip is filled in the ordinary manner and the bottom doors remain closed so long as the skip is on the ground or is suspended from the lifting chain, but are opened as quickly or gently as desired and without scattering, when the opening gear comes into operation and the lifting chain is lowered out, this being completely controlled by the crane man.

Advantages.—The skip can be used in connection with any crane which has about 25 per cent. more power than that required for lifting the 1-ton or whatever may be the net load.

In addition to the high speed of working above referred to, the wages of the man to manipulate the skip for discharge are saved, and all risk of accident to him is avoided.

Prices of these skips will be found at page 160.

TURN-OVER SKIPS of the kind referred to at page 161—where the prices of the ordinary sizes will be found—being inexpensive in cost and maintenance, are very generally employed for all materials which do not require special care.

TURN-OVER TUBS.—Coal which will not bear re-handling without deterioration is sometimes sent to port in wood or iron turn-over tubs of 2 to 4 or 5 tons capacity. The tubs are filled at the colliery and conveyed to the port of shipment on platform wagons which carry four or more tubs, and the latter are handled by fixed or portable swing jib cranes.

Arrangements of this kind are satisfactory for comparatively small output, but are scarcely desirable where large quantities must be rapidly and economically dealt with.

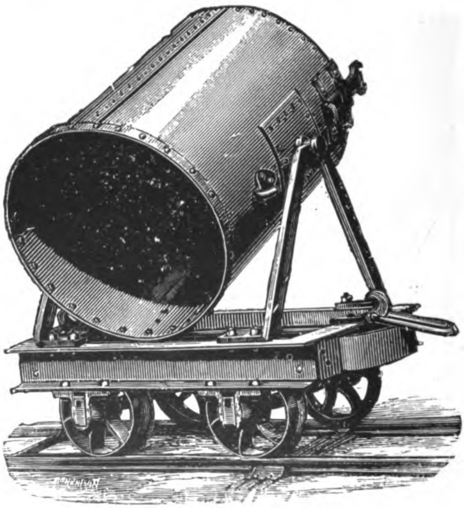


Fig. 5048.

SIDE TIP TROLLEY SKIP.—The engraving Fig. 5048, represents plant adapted for lowering into a ship and discharging coal or other materials at any point alongside an elevated or other narrow gauge track.

Provision is made for handling the skip by a crane and replacing it on the standards after it has been filled or emptied, as the case may be. The under-carriage is of wrought iron or steel with end spring buffers as indicated in the engraving, and the wheels are fitted for any gauge up to about 24 inches.

The capacity of the skips ranges from one-third to 1 or 1½ cubic yards, and the cost with trolley and draw bar as illustrated from about £12 to £25.

ANTI-BREAKAGE SKIPS.—These vary so widely in arrangement and capacity that the following brief descriptions must be taken to refer rather to systems than to details of construction, which necessarily have to be modified to suit local conditions.

SIDE-OPENING SKIPS, of whatever capacity, are usually rectangular, and contain a wagon load of coal, the upper end being larger than the body, and lower end fitted with side doors and appliances for opening them automatically or otherwise, as may be convenient.

Filling the skips.—The arrangements for this vary according to circumstances; the skip is usually manipulated by a jib crane, the contents of the wagon being in some cases emptied into the skip suspended by the lifting chain, but a better result is frequently attained by lowering the skip into a pit formed between the track rails and up-ending the wagon by hydraulic or other appliances to tip the contents into the skip.

Under this system the wagon never leaves the rails, so that no cradle is required. There is the further advantage that the wagons can be either of the ordinary type with end door, or "drop-bottom," and the skip can be lowered until it nearly (or quite) rests on the coal in the hold. The bottom doors being then opened, the coal rolls out whilst the skip is slowly lifted or slewed, as the case may be.

The skip is so nearly the same weight as the cradle that a crane which is suitable for one system is equally available for the other. For description of the cradle system see pages 71 and 72.

DROP BOTTOM WAGONS.—Where this form of rolling stock is used, the wagons can be easily arranged to be lifted by the crane and emptied when over the hold, but the higher initial cost and up-keep of this type of rolling stock, as well as their weight in relation to paying load are drawbacks under most circumstances.

TRANSPORT OF COAL, ORE, ETC.

RAILWAY TRANSPORT.—Wagons carrying 7 to 10 tons of coal are easily handled and are convenient in other respects, but the economy in cost of haulage effected by long trains of wagons of the largest capacity drawn by powerful locomotives, is incontestable, and the tendency in recent years, in this and other countries, has been to increase the carrying capacity of rolling stock, as far as this can be done without too serious interference with existing station siding and other facilities.

This subject is mentioned merely as one to which attention should be directed when additional cranes, traversers or other terminial arrangements are under consideration.

TRANSPORT BY WATER.—The foregoing remarks on land transport apply equally to transport by water, as shown by the increase in dimensions of steamers of modern construction, and the provision of every facility for loading, stowing and discharging cargo. The financial results of such provision is referred to in the remarks on new installations for the Manchester Ship Canal at page 58.

Although steamers usually carry their own machinery for loading and discharging, this work is frequently done much quicker by the dock equipment of plant, several types of which are referred to in this volume and in Section II.

INLAND TRANSPORT BY WATER.—Amongst the numerous arrangements for cheap transit by canal or river, trains of lighters may be mentioned, these having, for many years conveyed coal and ore at remunerative, although extremely low rates.

Trains of lighters.—These very successful installations consist of rectangular flat-bottom punts or lighters, constructed of wrought-iron and each carrying about 35 or 40 tons of coal.

The ends of the lighters are slightly rounded and fitted with central pin and bar connections, side buffers and draw chains similar to those on railway wagons. The train made up and coupled as above described, is towed to a tower at the shipping port which is provided with the hydraulic or other machinery requisite for raising the lighter to the height most convenient for discharge.

The lighter is floated over and firmly attached to a submerged cradle at the foot of the tower, the cradle and lighter being then raised to the height required for discharge; appliances for tipping then come into operation, and the contents of the lighter are thus emptied over a shoot which conveys them to the vessel's hold.

Speed of working.—The arrangements above described are modified to suit local conditions, but the installation now referred to lifts, discharges, and lowers the lighter and is ready to commence another operation in about eight minutes.

NEW INSTALLATIONS.—It is obviously impossible to deal with these exhaustively without full details of the conditions to be fulfilled and an indication of the capital outlay contemplated when—as must sometimes happen—this is a matter of importance.

If designs and estimates for the plant required cannot be made under the immediate supervision of those who will use it and advice thereon is desired, clear information on the above-named points should be furnished.

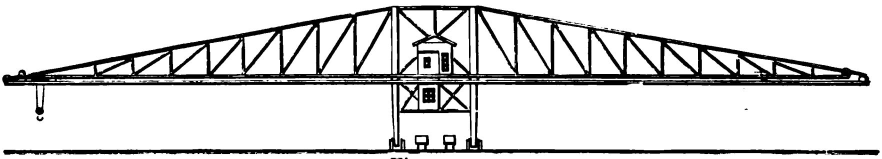


Fig. 5049.

CANTILEVER CRANES.—These usually consist of a tower built of steel sections and carrying a cantilever arm on one or both sides, as well as the gear for lifting, lowering, and traversing the load and (if required) for travelling the whole structure.

The proportions in lifting power, height above ground level, and length of jib, can be varied to any extent, and the latter can be made to rotate, but complication is avoided and expense saved if the motions are limited, as they are in the design illustrated, to traversing and travelling and these usually suffice for all purposes.

Double cantilever cranes.—Fig. 5049 represents a crane which manipulates loads of 5 tons at any point up to 155 feet on either side of the tower, but appliances are provided for handling loads of 13 tons within a range of 60 feet from the centre of the tower.

The load is taken up or deposited at any point in the length of traverse from the centre of tower to the end of jib, and stability is maintained by a counterweight which automatically traverses on one of the cantilevers, in unison with the traverse of the load on the opposite cantilever.

Tower and jibs.—These are constructed to provide maximum strength with minimum area exposed to wind pressure, and the greatest possible facilities are provided for handling materials, including transport beneath the tower, as indicated in the engraving.

Machinery.—The engine or electric motors and machinery for the above-named operations are carried in the central tower and controlled from the engine room, the height and position of which affords a complete view of the work.

CANTILEVER CRANES FOR BRIDGE, ROOF AND STEEL WORKS.—The mobility of these cranes, the small space occupied, and the great range of surface over which they efficiently operate, strongly commend them for employment where large quantities of materials have to be quickly and expeditiously dealt with, whether for temporary storage, erection or delivery.

It will be evident that a crane of this construction may, in some cases, be advantageously adopted in lieu of a Goliath, or an overhead travelling crane and gantry.

BUILDING BERTH CRANES for slipways. This subject is referred to elsewhere, and many special devices have been employed, a recent and highly successful development of plant for this purpose being a crane of the type Fig. 5037, mounted on a fixed gantry built between two slipways.

The height of the gantry, added to that of the tower, and the great range of traverse along the cantilever jib suffice to clear and reach all parts of the largest ship, so that the tower, being provided with self-propelling gear and the other motions already described, all materials are transferred to their proper positions without re-handling.

The high speeds of lifting, traversing and travelling which can be safely employed in connection with these rectilinear motions, effect an immense saving in space occupied, as well as in time and cost of handling.

Railway tracks for conveying materials are usually laid between the rails which carry the tower, thus utilising the space to greatest advantage.

FLOATING CANTILEVER CRANES.—A modification in the mode of construction above described is adopted for floating cranes of large power. This admits of the crane pontoon being moored alongside a vessel and having guns or heavy machinery transferred from one side to the pontoon, and deposited in the vessel at a distance of 40 to 50 feet beyond the side of the pontoon, and at a height of 50 feet or more above water level.

The requisite stability is maintained by the use of water ballast which keeps the pontoon on an even keel in the same manner as floating cranes of the type, Fig. 5003.

The deck equipment is similar to that described at page 20, and the pontoon is easily adapted for carrying or storing heavy guns, or for equipment with plant suitable for repairs or renewals of machinery.

The small extent to which the foregoing suggestion has been adopted, seems to indicate that it has not yet received the attention it deserves.

CONVEYORS OR TRANSPORTERS.

Where ore, materials or merchandise have to be quickly and cheaply transferred to distances which are beyond the capacity of cranes, conveyors of the types now referred to will probably give very satisfactory results.

It may be desirable, in some cases, to make special studies of the conditions under which the work can be most profitably performed, but one or other of the appliances, examples of which will be found in the following pages, are suitable (or very nearly so) for most of the conditions usually to be dealt with.

Rope-way conveyors.—Under some circumstances this system may be preferable to that now illustrated, and information thereon will be found at pages 84 to 89.

Over-head transportation.—In addition to the saving in time and in the cost of handling effected by over-head transportation, other advantages may be mentioned which are frequently of equal or even greater importance.

Amongst these are :

The entire absence of interference with road traffic or industrial operations.

The limited frontage or space required for transmission and the small area occupied by plant.

The faculty of picking up, depositing or otherwise discharging minerals, merchandise or materials of any kind, at any point irrespective of distance, and without re-handling.

General arrangement of machinery.—However greatly the plant may be modified in design, strength or arrangement of parts, the mechanical details remain substantially as follows :

Lifting and traversing.—These motions are transmitted by steam, electric or other power, directly or by belt as may be convenient, the winch having a barrel which will carry the length of flexible steel wire rope required, and appliances for stopping or starting, to pick up or deliver the load at any point in the length of traverse, all operations being controlled by the winch man.

The rope from the winch passes around the dumping fall block, as indicated in Fig. 5055, so that the operations of lifting, traversing and lowering the load are performed by hauling in and paying out a single rope.

The winch may be immediately below the boom or in any more convenient position.

Speeds of lifting and traversing.—Loads of 1 to 2 tons are frequently lifted at speeds up to 300 feet per minute, and traversed in either direction at a speed of 800 to 1,000 feet per minute, both operations being under complete control; in practice, however, it is better to limit the speeds of lifting and traversing to those which can be usefully employed, because excess in these involves higher cost of plant and greater wear and tear.

The boom is usually of steel, box section, supported in any convenient manner, either horizontally or with an incline, so that storage can be effected to any height usually required. If the boom is suspended it can be slewed to right or left (and probably traversed) to command a large area.

Portable and fixed conveyors.—The length of boom and traverse is necessarily more limited for portable than for fixed conveyors, but many of the former are in use with booms of great length, and mobility is sometimes a very important feature.

The savings effected must obviously vary with the conditions to be fulfilled; in one instance they are represented by the wages of six men previously employed in tramming, stacking, &c.

Work performed.—One of these conveyors with a steel boom 80 feet long and a cross traverse of 40 feet is capable of making 60 operations per hour with loads of 1 ton, each operation consisting of lifting, traversing, lowering, discharging, and returning ready for the next load; but with this, as with other kinds of lifting machinery, the quantities dealt with are limited by the speed at which loads can be prepared and removed, and the actual duty rarely exceeds 40 tons per hour.

The details required for preparing designs and estimates are principally as follows :

Whether portable, fixed or floating plant is required.

The kind and quantity of materials to be handled per hour.

The average and maximum weight and dimensions of loads.

The maximum distance between points of loading and discharge.

Dimensioned sketch of site or buildings to be equipped.

If electric driving power is preferred, state nature of current available (if any).

Details of steam or electric power (if any) available for driving the winch, and present position of same.

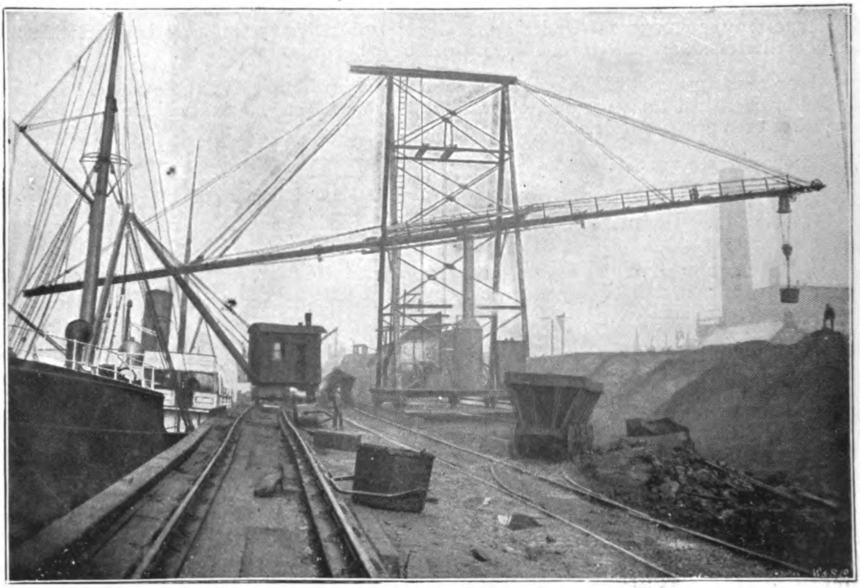


Fig. 5050.

PORTABLE OR FIXED TOWER CONVEYORS.—Fig. 5050 represents a steel structure mounted on an under-carriage with wheels, and complete with engine for hoisting and traversing, boiler, steel boom, travelling blocks and gear, flexible steel wire rope and all usual accessories.

The ordinary load of 27 cwt. is deposited where desired within a range of about 135 feet. The speeds of lifting and traversing are, respectively, up to about 300 and 900 feet per minute, but are under complete control. Conveyors of similar type are constructed for much heavier loads, as indicated in the diagram engraving Fig. 5049, the range of traverse, speeds, &c. being arranged to suit the conditions desired.

The projecting boom is hauled up to offer no obstruction to shipping when the machine is not at work, and similar arrangements—either portable or fixed—are evidently adaptable for dealing with merchandise or materials of the most diverse character.

FLOATING TOWER CONVEYOR.—For this purpose a tower, similar to that illustrated by Fig. 5050, is fixed on a barge, pontoon, or other suitable vessel, the boom having the projection, on each side of the tower, requisite for transferring from ship to quay, or the reverse, as desired.

FLOATING MAST CONVEYOR.—A useful and inexpensive form of conveyor, for lengths up to about 50 feet, consists of a boom, complete with travelling block, which is lashed to one of the masts of the vessel to be loaded or discharged, and guyed fore and aft in the most convenient position. The ship's winches are usually available for the supply of motive power.

PORTABLE OR FIXED GANTRY CONVEYORS.—A boom, similar to that last referred to suspended from a gallows, or gantry forms an economical and satisfactory arrangement for handling coal, grain, merchandise, etc.

The boom can be slewed to right or left and is easily traversed across the gantry beam to increase the area for stowage. The driving power can be fixed in any convenient position.

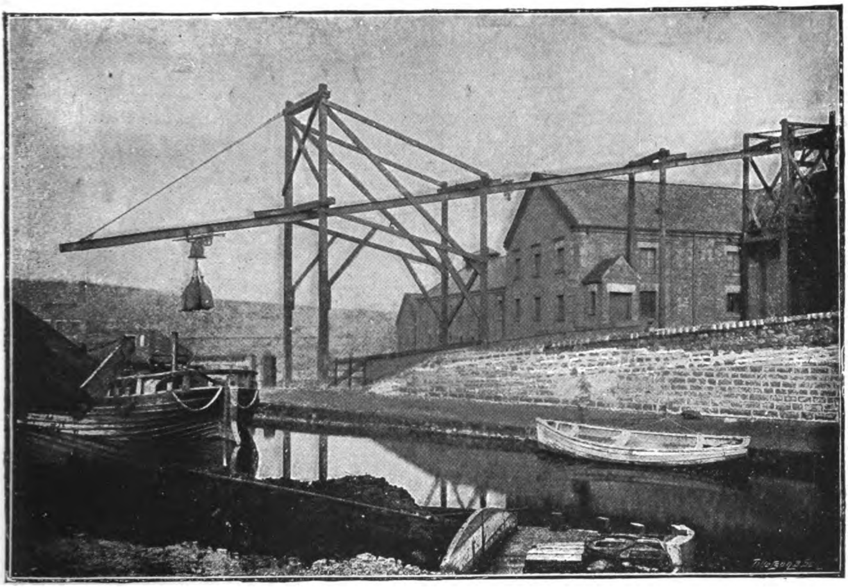


Fig. 5051.

FIXED CONVEYOR.—Arrangements similar to that now illustrated may be adopted with advantage where interference with the road-way between, or in front of buildings is inconvenient, if not inadmissable.

There is scarcely a limit to the length of traverse and, as will be seen, the structural work is so simple that it can usually be provided locally ready to receive the machinery.

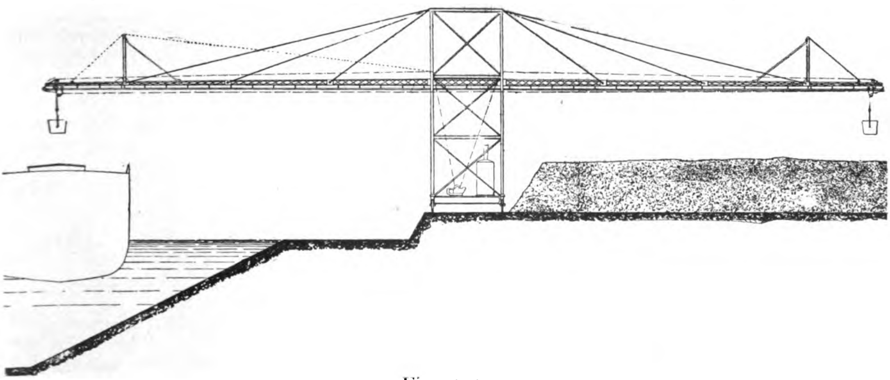


Fig. 5052.

CANTILEVER CONVEYOR.—The diagram engraving Fig. 5052 illustrates a type of plant which occupies a small quay space, but commands a large area for storage of coal, ballast, dredge spoil, timber, etc. or for depositing them on wagon.

The plant, whether fixed or portable, is self-contained and will handle 50 to 100 tons per hour. The boom can be raised to have no over-hang beyond water-line.

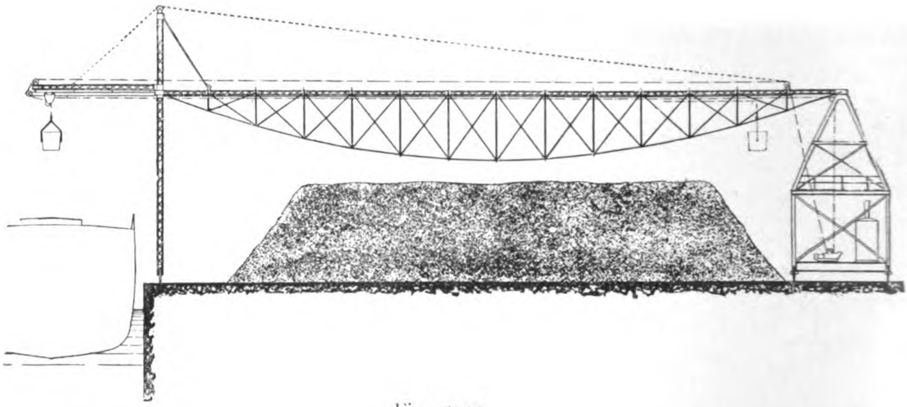


Fig. 5053.

BRIDGE CONVEYORS.—The advantage of this arrangement over that last referred to, is, that the bridge—being supported at both ends—can be built of any span or height desired, with faculty of loading up, or discharging, anywhere between the two supports. Lengths, between supports, up to 150 feet, or more, and heights up to 30 or 40 feet, present no difficulty.

The machinery which drives the lifting and cross-traverse motions is fixed in the tower—usually constructed of steel—and can be controlled from the lower or upper platform as may be convenient.

The working capacity of a double-track conveyor is 50 to 100 tons per hour.

PORTABLE BRIDGE CONVEYORS are constructed as illustrated by Fig. 5053, and above described, both front support and tower being mounted on wheels for travelling longitudinally, so that the area for storage is limited only by the length of quay available.

If necessary the structure can be moved by power transmitted from the lifting and traversing winch.

COMBINED PORTABLE AND FIXED TRANSPORTERS.—Considerable outlay for plant for long distance conveyance may sometimes be saved by having a portable transporter, somewhat similar to that indicated in Fig. 5052, to work in combination with any number of fixed overhead conveyors, constructed of girders supported by iron or timber posts, which can be carried to any length required.

The portable transporter travels along the line of quay and transfers coal, ore, merchandise, &c. to or from wagons on quay, warehouse, or fixed conveyor, the projecting arm or jib which reaches the centre of steamer's hatchway being triced up to clear masts and rigging, when desired.

Appliances are provided for taking up the load, or discharging it automatically, at any point in the length of traverse, so that the number of operations performed in a given time depends principally on the distance the load has to be carried, but may probably average from 30 to 60 per hour.

Information required.—As installations of this kind must be constructed to suit local conditions, it is essential that drawings to scale, or with figured dimensions, should be supplied, also details relating to the kind of work to be performed, the buildings to be served (if any), and whether steam or electric power will be preferred.

As regards weight to be carried, about 1 ton is usually convenient as a maximum load.

CONVEYORS FOR STORES, FACTORIES, &c.—The system represented by Fig. 5054 admits of endless modifications in length and distance of traverse, either on the level or at any incline, with the faculty of taking up or discharging the load where desired, and is largely used in warehouses as well as for storing coal, grain, ore and innumerable materials brought by land or water.

The driving machinery worked direct by engine or other motor, or by belt as indicated in the diagram, is fixed in any position which admits of the rope being carried to the longitudinal boom, and the driver having a proper view of his work.

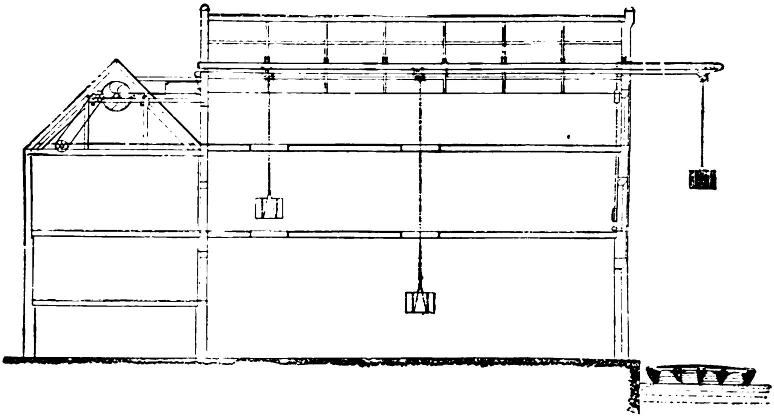


Fig. 5054.

The traversing gear consists of a steel boom of box section with flanges for the wheels of a lifting and traversing carriage which conveys the load; this can be automatically arrested and held in position at any point desired, and all motions are worked by a single steel wire rope.

The lifting capacity of the plant illustrated is 1 ton at high speed, but the lifting power, the arrangement of parts, and the overhang of the jib can be modified to any extent desired.

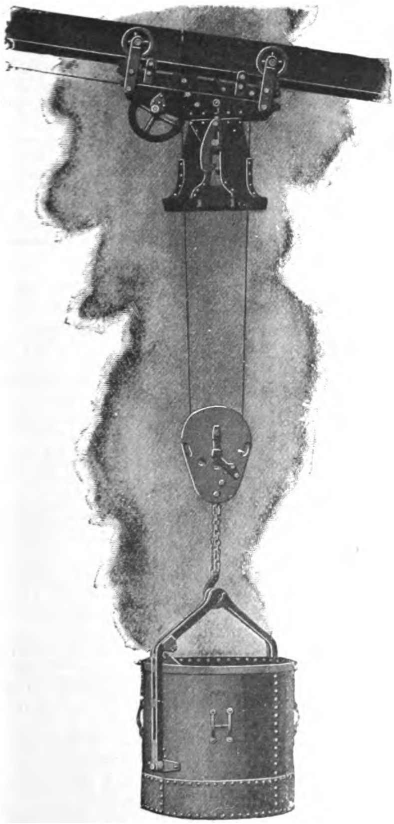


Fig. 5055.

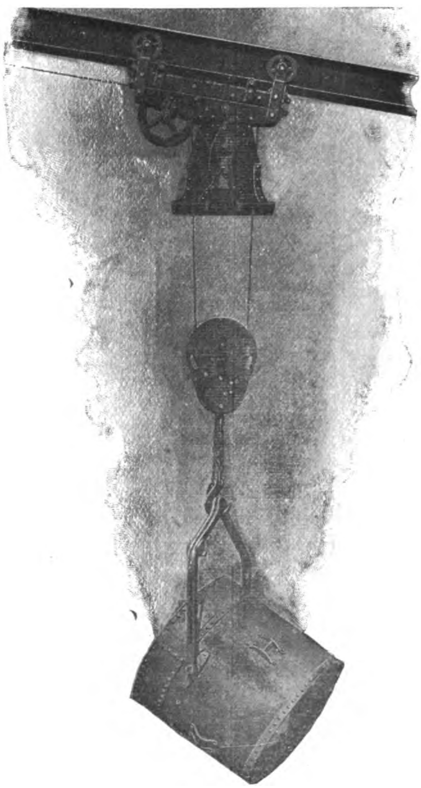


Fig. 5056.

CONVEYOR WITH AUTOMATIC DUMPING SKIP.—The engraving Fig. 5055 represents the skip being lowered for emptying, and Fig. 5056 shows it when emptied and returning to the vertical position ready for the next journey.

The advantages offered by this invention are :

1. That the upsetting gear can be adjusted to come into operation, automatically, at any point desired.
2. That heavy or friable matter (coal, etc.) can be discharged with minimum shock or breakage, as the case may be.
3. That no time being lost by delay in upsetting the skip, there is a corresponding increase in the quantities dealt with in a given time—frequently 20 per cent. or more.
4. The wages of men to upset the skips are saved.
5. The absence of risk of injury to men when tipping slippery or hot materials.

The boom can be made of the length most convenient for the work, and it can be slewed to deposit over a large area. All motions are operated by the driver of the hoisting machinery.

The framework carrying the boom and (if necessary) the hoisting machinery may be fixed or portable and be constructed in steel, iron, or timber, as may be best adapted for the local conditions.

Information required.—The engravings and the foregoing description will indicate the kind of details necessary for the preparation of designs and estimates for the complete plant.

APPROXIMATE PRICES OF DUMPING FALL BLOCK, Figs. 5055 and 5056.

Lifting power of gear ... ... cwts.	25	35	50
Price of gear only	£30	£45	£55

APPROXIMATE PRICES OF DUMPING SKIPS, Figs. 5055 and 5056.

Capacity of skip ... ... cubic feet	10	20	30	40
Price of skip	£15	£16	£18	£19
Approximate weight... ... ... cwts.	4 1 21	5 3 7	6 3 0	8 2 17

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

SUSPENDED CONVEYORS are usefully employed in transferring coal, or comparatively light loads in workshops, factories, power installations, etc. and for handling parcels or packages in railway passenger or goods stations.

The conveyor truck, with electric motor, travelling and lifting gear and seat for the attendant, is carried on girders which are suspended from a roof, or from columns at any convenient height, so that the transfer is effected without in any way interfering with operations at ground level.

Powers and speeds.—These conveyors are made of two powers, the smaller one to deal with loads up to 15 cwt. the larger one being equal to two tons.

The speeds of lifting and traversing can be varied to any extent, but speeds of 26 feet per minute for lifting, and 500 to 700 feet per minute for travelling are usually satisfactory.

PNEUMATIC HOISTS.—The extensive use of compressed air in connection with drilling, rivetting and other tools, has led to the introduction of pneumatic hoists. They are inexpensive and as similar pressure is required for working both tools and hoists, no special provision is required for the latter, excepting the requisite capacity in air-compressing plant.

Fixed and portable hoists.—The cylinders for the former are suspended from a roof, bracket, etc., those for the latter being carried on a trolley which runs on the horizontal arm of a crane jib, or on an overhead girder in the manner (and for most of the purposes) last described.

The compressed air is conveyed to the lifting cylinder by flexible tube and all operations are easily controlled, at floor level, by chains connected to the air admission valve spindle.

Capacities of hoists.—The cylinders are made of any required dimensions, but those in common use range from 4 to 12 inches in diameter and 4 to 7 feet long.

With an air pressure of 60 to 100-lbs. per square inch (which is ordinarily used for tools) a hoist 6 inches diameter will lift 9-cwt. to 20-cwt. and consume 4 to 6 cubic feet of air for a lift of 4 feet.

A hoist 12 inches diameter will lift 2½ to 4 tons to a height of 4 feet, the consumption of air being 15 to 25 cubic feet.

Information required.—The points to be principally considered are :

Whether the hoist is to be fixed or portable.
The diameter and length of cylinder required, or
Details of the work to be performed.
The pressure of air available (if any), and
The maximum distance through which the air has to be conveyed.

PRICES OF VERTICAL PNEUMATIC HOISTS.

Lifting power with 75-lbs. pressure, lbs.	950	1450	2000	2800	3800
Diameter of cylinder ... inches	4	5	6	7	8
Height of lift ... ... feet	4	4	4	5	5
Price of hoist	£8	£10	£12	£14 10	£16 10

For higher lifts add 20 per cent. for each extra foot of height of vertical lifts and 10 per cent. for horizontal hoists.

PRICES OF HORIZONTAL PNEUMATIC HOISTS.

Lifting power with 75-lbs. pressure, lbs.	450	700	1300	1750	2300
Diameter of cylinder ... inches	4	5	6	7	8
Height of lift ... ... feet	7	7	7	7	7
Price of hoist	£22	£24	£26	£28	£30

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

ROPE-WAYS.

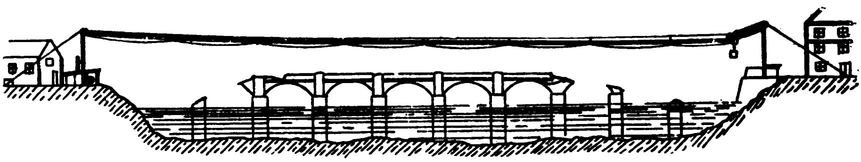


Fig. 5057.

FIXED AND PORTABLE ROPE-WAYS.—Fig. 5057 represents a fixed installation which carries a maximum load of four tons through a span of about 930 feet, and is capable of dealing with 70 tons per hour ; but the same system is easily adapted to convey any reasonable load horizontally or at any incline (up or down) between 5° and 50°, the speed of lifting and traversing being merely a question of strength of cables and of power provided for the purpose. It will, therefore, be seen that rope-ways can be modified to suit innumerable conditions and to constitute a kind of conveyor exceeding the capacities of those referred to at pages 77 to 81.

The towers which carry the steel wire rope-way are constructed of steel or timber for any height or span, and may be fixed or portable as circumstances require. Mobility is frequently of great value, as, for instance, in conveying the spoil from canal, trench, quarry, or other excavation, and depositing it where required for removal without any manual labour, and under conditions which do not admit of the use of cranes, locomotives, or similar forms of hoisting and tractive appliances.

Steam or electric power.—The machinery which transmits power for all operations is fixed on one of these towers, and all motions are easily controlled by one man. But, where several sets of plant are used, or where power can be obtained from an electric lighting station, much may be said in favour of substituting an electric motor for the usual engine power.

Arrangements of this kind obviously afford great facilities for removal of plant, and largely increase the flexibility of the system.

FIXED ROPE-WAY.—The towers represented in Fig. 5057 are built of pitch pine, the height is 77 feet, and they are tied to suitable anchorages by steel wire rope stays.

The span (as above-mentioned) is 930 feet, the lifting power is four tons, and the carrying capacity about 70 tons per hour.

The speed of lifting is 350 feet per minute, and that of traversing, about 700 feet per minute.

LIFTING AND HAULING MACHINERY.—A double cylinder engine, with link reversing motion, drives two rope drums, one for lifting and the other for the traversing rope. Both drums are provided with clutches so that the hauling drum may remain stationary when the load is lifted, or both may be worked when it is being traversed, and so maintain uniform height until lowering out is required. Provision is also made for preventing excessive "sag" in either the lifting or hauling ropes.

Work performed.—This consisted of the rapid demolition of an existing bridge, the materials—about 130,000 tons—being traversed and deposited on either bank, or at any intermediate point, at the lowest possible cost and without interference with the river traffic: also for similar service in the erection of the new structure.

Efficiency.—The work was conducted with great regularity, and when the new bridge was completed, the plant was, for all practical purposes, as good as when first put to work.

The working expenses, including maintenance of plant, is remarkably low.

VIADUCT BUILDING.—Another example of the utility of this system is furnished by its employment in the construction of a long viaduct, which included the formation of piers in concrete to a height of 73 feet, without scaffolding.

One of the prominent advantages of the rope-way was that continuity of progress was secured by concreting at any of the piers during the time that which had been recently deposited in the others was setting; it may be added that the ribs for centering were also manipulated by the rope-way.

Evidently, therefore, this or some similar arrangement can be advantageously employed under conditions which would be less satisfactorily fulfilled by cranes or other well-known lifting appliances.

INFORMATION REQUIRED.—Substantially, this is as indicated at page 79.

PORTABLE ROPE-WAYS.—It was necessary that the plant now referred to should follow up a long line of excavation and take up or deposit its load at any point within a range of about 2000 feet.

The materials conveyed consisted principally of soil and broken stone; these were carried in self-discharging skips, but there were also a considerable number of large stones of various sizes and weights up to about six tons each. The largest stones were lifted and carried by strong nippers or "dogs" with automatic release, and the others in cradles.

Towers.—The main rope-way is supported by towers constructed of steel and mounted on trucks. These travel on heavy tracks laid in short sections and shifted from back to front as the work proceeds. The tower trucks can be propelled by power, but hand winches hauling on chains with anchorages, or even pinching along, usually suffices.

Machinery.—The engines, boiler, and gear for hoisting, cross traverse, and tipping are fixed on one of the towers, and all operations—in any combination—are controlled by the driver.

Working Expenses.—The average cost of lifting, traversing and depositing the materials was about 2d. per cubic yard of materials handled.

This data will serve as an indication of the probable cost of removing materials when working with plant of this type, even if of different capacity.

Information required.—This is similar to that mentioned at page 79.

ROPE-WAYS FOR QUARRIES, EARTH WORKS, &c.—As neither weight transported, inequality of surface, span between supports or inclination of rope-ways materially interfere with efficiency, they are employed with great advantage in stripping and bareing, and for conveying the refuse to a distance most convenient for future operations, as well as for eventually transporting and depositing the saleable products on railway wagon or other vehicle.

Arrangements of this kind are obviously valuable in the formation of embankments, dams, and other works of construction.

ROPE-WAYS FOR FACTORIES.—Similar remarks, of course, apply to many industrial undertakings where cheap and rapid transport are essential to commercial success.

SELF-ACTING ROPE-WAYS are referred to at page 88.

SKIPS FOR ROPE-WAYS.—Facilities for loading and discharging skips or boxes so directly affect the speed and cost of working, that details relating to this portion of the plant need to be carefully considered, but these must almost invariably be devised to suit the materials and conditions of transport.

WIRE ROPE TRAMWAYS.

The travelling endless wire rope with carriers running by frictional contact is illustrated by Fig. 5058, and the fixed wire rope with carriers hauled by separate rope, as indicated in Figs. 5059 and 5057, substantially represent the types in general use, although modifications must frequently be made to suit special conditions.

Both systems are used for conveying coal, ore, materials or merchandise for storage, treatment, shipment or other delivery, and either works quite satisfactorily at a considerable angle or gradient.

The first named—the endless rope—conveys any number of comparatively light loads quickly and economically, about 5 cwts. being a convenient maximum limit.

The fixed rope system is usually employed where loads each weighing, perhaps, several tons have to be carried, or where circumstances require long spans between supports.

Each system therefore has its sphere of usefulness, and working expenses and cost of maintenance are remarkably low in either of them.

COST OF WIRE ROPE TRAMWAYS.—Although accurate estimates of cost cannot be made without details of the kind mentioned at page 87 the tabulated approximate cost of the principal materials required for a line of given length and carrying capacity which will be found at pages 87 and 88, and will suffice for most preliminary estimates, due allowance being made for the cost of supports and terminal structures, towers, or exceptional features.

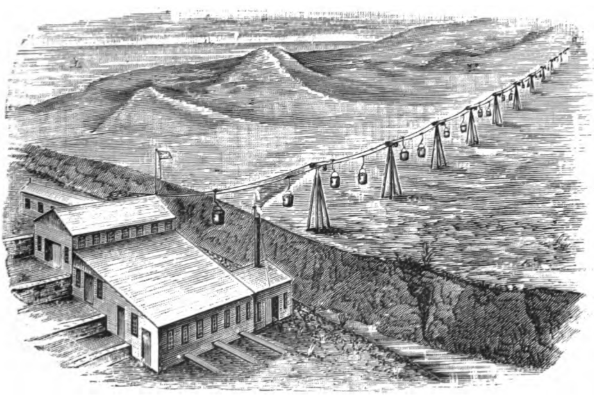


Fig. 5058.

ENDLESS ROPE TRAMWAYS.—The steel wire rope is of great strength and durability and usually travels at a speed of about 350 feet per minute.

Supports for rope.—These are of timber or iron (usually the former), the height above ground level being varied to suit irregularities of surface, or to maintain approximately similar gradients, but a clear height of about 15 feet, and spaces of about 150 feet between supports are usually convenient. The following tables of approximate cost are based on these dimensions, but the supports may be as much as 500 or 600 feet apart, if necessary.

The carriers from which the skip, cradle or other receptacle for the load is suspended, consist of a steel frame mounted on wheels grooved to clip the travelling rope and pass freely over pulleys, provided at intervals, for supporting the rope and preventing undue "sag."

The skips, boxes, etc are of any form most convenient for the load to be carried, such as skips for coal or minerals, open or closed boxes for merchandise, slings or cradles for casks, bags, sugar cane and other products.

Automatic appliances can be arranged for loading at one point and for discharging the load at any point in the line traversed.

The cost of the metallic work for automatic discharge, ready for fixing, will probably be ... ... £60 to £70

Driving and tension gear.—The approximate cost of these, and of shunt rails will be found in the following table, but the cost of engine or other driving power cannot be ascertained without the undermentioned details.

Information required:

The total length of line with plans and sections of the ground, showing the gradients, spans (if exceeding 150 feet), and the number and degrees of angles (if any) to be provided for.

The kind of materials, and quantity to be dealt with in a given time.

The driving power to be used.—If this is provided by the purchaser, state how much power is at disposal and the speed in revolutions per minute of the shaft from which power will be supplied.

CONVENIENT LOADS FOR ENDLESS ROPE TRAMWAYS, Fig. 5058.

Carrying capacity of line .. tons per hour	5	10	20
Approximate weight in each carrier ... lbs.	100 to 120	120 to 170	170 to 250

APPROXIMATE COST OF PLANT FOR ENDLESS ROPE TRAMWAYS, Fig. 5058.

Carrying capacity of line ... ... Tons per hour	5	10	20
Rope, pulleys, and rolling stock for one mile Price per mile	£310	£460	£580
Driving and tension gears and shunt rails Price for one mile of line or less	£60	£130	£170
Rope, pulleys, &c. as above, for more than one mile but less than three miles of line ... Price per mile	£340	£490	£620
Driving and tension gears and shunt rails for any length between one and three miles ... ... Price	£120	£250	£300
Angles for any degree of deviation ... Price each	£25	£35	£45

The cost of packing for shipment and delivery f.o.b. will probably be about 5 per cent.

Example of estimate for an endless rope-way ¾ mile long to carry 5 tons per hour:—

Rope-way, pulleys and rolling stock for ¾-mile at £310 per mile ...	£232	10	0
Driving and tension gears for terminals	£60	0	0
Cost of materials for ¾-mile of rope-way ...	£292	10	0
If with curve or angle add £25, making the total cost	£317	10	0

The cost of timber supports, 15 feet high above ground level, will probably be £4 to £5 each, and 30 to the mile is the average number required.

If these are to be provided, the above figures will be increased by the cost of (say) 23 supports, amounting to about £100.

SINGLE FIXED ROPEWAYS.—This system, indicated in the diagram, Fig. 5059, is adopted for transporting light or heavy loads on long spans, on the level or with steep gradients, as much as 5 or 6 tons on spans of 2000 feet, or more on steep gradients, having been successfully dealt with.

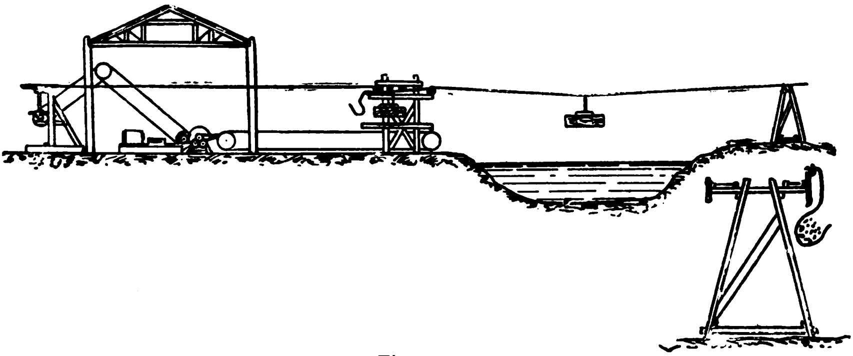


Fig. 5059.

The arrangement of plant differs materially from that represented by Fig. 5058, inasmuch as the load is carried on a strong steel wire rope which serves as a rail, the cradle, which carries the load, being hauled by light steel flexible rope.

Gradients.—This type of ropeway can be laid in the level, or in a series of inclines varying in length and gradient, the speed of travelling, on up or down grades, being completely controlled by the hauling rope, so that there is no waste of power and very little wear and tear.

The cost of these ropeways is usually less than those of endless rope tramways of equal length and carrying capacity.

DOUBLE FIXED ROPEWAYS are more expensive than those last referred to, but are preferable where heavy loads are to be carried or where gradients are very steep.

The two carrying ropes are supported on saddles and the cradles (or carriers hauled by endless wire rope) run on grooved steel wheels which bear on both ropes, the load being suspended between them.

Cost of materials.—The following approximate estimate of the cost of materials for lines of this type will probably be useful, it being understood that the spans for lines of aggregate carrying capacity up to 10 tons per hour are assumed to be 1000 feet, and those for 20 tons, 600 feet. If longer spans are required the cost is slightly increased.

Plant for heavy loads must be specially designed, and the cost estimated, after the details of spans and maximum weight of single pieces to be carried, have been arranged.

PLANT FOR DOUBLE FIXED ROPEWAYS.

Carrying capacity ... tons per hour	5	5	10	10	20	20
Maximum gradient	1 in 10	1 in 3	1 in 10	1 in 3	1 in 10	1 in 3
Price of materials for 1 mile of line ...	£1100	£1170	£1330	£1530	£1680	£1820
,, ,, 2 miles of line ...	£1790	£1950	£2400	£2660	£2990	£3290

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

SELF-ACTING ROPEWAYS.—The ancient and well-known system of utilizing the weight and momentum of descending loads for hauling up the empty carriers, is peculiarly adapted for rope transport.

Thousands of tons have been carried by such ropeways with down grades of all inclines up to 1 to 1, and spans of more than 5000-ft. with great satisfaction to the owners.

With properly arranged brake power, the attendant completely controls the work, and the plant can be adapted for transporting loads in single pieces of any reasonable weight; it is less costly than that last referred to.

ROPE HAULAGE.—The two systems of surface haulage known as the "Tail rope" and the "Endless rope," each have their advantages for service in connection with mines, quarries, brickfields, etc. and the following notes relate to the conditions under which each usually gives the best result.

Tail rope haulage is preferable where long trains have to be hauled over undulating ground, and specially so if branch lines have to be served.

Machinery required.—This consists of an engine or electric motor, and gear for driving two drums independently of each other. One of these drums carries the requisite length of flexible steel wire rope and the other the tail rope, and either of these will coil in whilst the other is paying out.

Mode of working.—The tail rope hauls the empty trucks or tubs into position for loading and is then disconnected. The main rope drum being connected, brings in the loaded trucks and the tail rope, which is attached to the end of the train, pays out at the same speed as the main rope coils in.

The track is provided with rollers to support the ropes, the dimensions and spacing of these varying widely according to circumstances.

This system has been largely used—especially in the North of England—with complete success, but the great flexibility and convenience of light railways and locomotive traction referred to at pages 90 to 105 have probably interfered with its adoption in some recent installations.

The cost of haulage by this system, or by endless rope, is usually about 2d. per ton per mile.

Endless rope haulage may be used with single or double tracks and adapted for hauling trains at speeds up to about 6 miles per hour over fairly level and straight lines, or with easy curves.

Machinery.—For a single line the engine has reversing motion, and gear for driving a drum to take an endless steel wire rope which traverses the whole length of the line and passes around a sheave at the far end.

The trucks are connected to the rope by clips or chains, and if the line is double, one serves for loaded and the other for empty trucks, without reversing the engine as is necessary where only a single line is laid.

As already mentioned the cost of working is about the same as by tail ropes, viz. : about 2d. per ton per mile.

CLIP FOR ROPE HAULAGE.—The clip is fixed at the front of the truck under-carriage and the hauling rope passes beneath it. The truck is attached to or detached from the rope by slightly moving a lever to the right or left as the case may be, but the clip can be arranged to release automatically at the end of the line, or elsewhere in the line of traverse, if desired.

LOCOMOTIVES AND ROLLING STOCK.

Surveys and studies for new lines of railway to determine the route most favourable for traffic, and for gradients which so largely affect cost of construction and subsequent working expenses, are usually carried out under the direction of the engineer-in-chief, and any attempt, without close investigation, to deal with questions so complex and far reaching would be mere waste of time. But the following general information, illustrations, approximate prices, etc. relating to useful types of locomotives, rolling stock, rails and equipments for narrow gauge and portable railways will probably be of some service when subjects of the kind are under preliminary consideration.

Attention is directed to the preceding introductory remarks bearing on these matters, and to the fact that the cost of all railway plant necessarily varies in sympathy with fluctuations in current rates for materials and labour, which form the principal items in cost of production.

Outline specifications are adopted in order to convey information concisely, and without too much repetition, relating to general dimensions and capacities, it being understood that the proportions of parts not specified are ample for the duty contemplated.

Materials and workmanship.—It will also be understood that due attention is paid to the quality of the materials employed, uniformity and interchangeability of parts and accuracy in fitting and finish.

GAUGES OF LIGHT RAILWAYS.—If a local or branch line differs in gauge from the main line it is destined to serve, the International Railway Congress recommend 2-ft. 6-in. or 2-ft. gauge as preferable to all others. The reasons for this conclusion are, that lines of these gauges may be laid with curves of 1½, or even 1¼ chains (30 to 25 metres) radius, and so follow almost any sinuosities likely to be required for connection, by sidings or portable railway, with adjacent factories or agricultural land.

CAPACITIES AND TYPES OF ROLLING STOCK.—The question : "What is the most economical capacity of goods trucks or freight cars, taking into consideration first cost, operative length of haul, character of traffic, bulk of consignment of truck or car, direction of traffic, etc." was submitted for discussion before the International Railway Congress, and is now mentioned because it seems to comprise the elements which require careful attention when the types and dimensions of new railway wagons are under consideration.

PAYING AND DEAD LOAD.—The ratio of paying to dead load being about $1\frac{3}{4}$ to 1 for trucks of 4-ft. $8\frac{1}{2}$-in. gauge and about 3 or 4 to 1 for narrow gauge trucks, the latter offers less inducement to traffic managers, than the former, to keep back freight until a truck load is obtained, and thus delay deliveries.

NARROW GAUGE PERMANENT WAY.—Before proceeding to illustrate and describe the leading types of rolling stock and equipments, it may be well to examine the relative cost of railways of different gauges and (roughly defined) different local conditions.

Approximate cost of railways.—The following table, based on figures compiled by the International Railway Congress, conveys a good idea of the approximate amount of capital outlay necessary for a high-class line on any of the gauges referred to, and these in juxtaposition affords some basis for estimating whether (directly or indirectly) the line will yield an adequate return on the requisite capital.

The cost of land is not included in any of these estimates, nor is allowance made for long inland transit charges, both being unknown quantities, but otherwise the figures represent the estimated cost of the line when laid and fully equipped.

Rolling Stock.—The vehicles may have a width of 6-ft. 8-in. and thus admit of comfortable accommodation for passengers, and, if the line is laid with steel rails weighing 30-lbs. per yard, engines up to 25 tons weight may be used. These engines are capable of hauling 220 tons over gradients of 1 in 100, or of travelling, for passenger service, at a speed of 35 miles per hour.

COST OF SUBSIDIARY RAILWAYS.—Pioneer lines of railway through fairly level country, and districts in which the traffic would not warrant the expenditure necessary to provide thoroughly equipped lines, have been constructed in New South Wales, at costs ranging from £1691 to £2019 per mile.

The ordinary main line rolling stock is used, and is hauled by a light class of engine at speeds of 15 to 20 miles per hour.

More than 100 miles of such lines were in operation in 1897, and the system is being extended.

COMPARATIVE COSTS OF RAILWAYS.—The low capital outlay for a line of 2-ft. 6-in. gauge is due principally to the lower cost of construction in formations, radius of curves, &c. The following is a forcible illustration of the relative cost of light and ordinary main line railways, both of normal (4-ft. $8\frac{1}{2}$-in.) gauge, and both constructed in England.

The length of line is nearly 13 miles, with three intermediate stations. Under ordinary conditions the line would have cost £450,000, or about £30,000 per mile, whilst the outlay for the light line was £67,000, or about £5,150 per mile.

The following table gives the average approximate cost of light railways suitable for various local conditions.

APPROXIMATE COST OF RAILWAYS PER MILE.

Gauge of rails ...	4-ft. $8\frac{1}{2}$-in.	Métre	2-ft. 6-in.
Level country ...	£2,392 to £3,987	£1,595 to £2,551	£1,260 to £2,057
Slightly undulating...	£3,652 to £5,582	£2,392 to £3,987	£1,595 to £2,392
Very undulating ...	£4,785 to £7,179	£3,652 to £4,875	£2,057 to £3,190
Slightly hilly ...	£6,380 to £9,571	£3,987 to £5,582	£2,392 to £3,987
Very hilly ...	£8,742 to £11,163	£4,785 to £7,178	£3,652 to £5,582
Slightly mountainous	£10,365 to £12,760	£6,380 to £8,774	£4,785 to £6,380
Very mountainous ...	£11,963 to £15,950	£7,977 to £11,164	£5,183 to £7,976

Rails, Sleepers and Fastenings.—The cost of these per mile of Railway is influenced by many circumstances other than fluctuations in the market price of the materials, and accurate estimates cannot be made without complete information on the conditions to be

fulfilled. The following figures, however, represent the approximate cost per mile of road of the different gauges and weights of rails, laid in this Country and in the Colonies or the East, including rails, steel sleepers, points and crossings, freight and insurance, and labour in laying and ballasting, but they do not include the cost of rolling stock, land, import duties or inland transport.

APPROXIMATE COST OF NARROW GAUGE LINES.

Guage of Rails ... ... inches	24	30	30	Metre
Weight of Rails per yard lbs.	20	25	30	50
Cost per mile laid in England	£575	£735	£840	£1590
,, ,, ,, Colonies or East... ...	£750	£955	£1093	£2040

Steel or Wood Sleepers.—Unless wood of suitable quality and moderate price is available locally, it will almost certainly be desirable to have the line complete with steel sleepers. They are four times more durable than wood and form a much firmer road for light traffic, with corresponding reduction in cost of maintenance.

Trucks.—For short lines of narrow gauge with much intermediate traffic, four wheel trucks of the type indicated in Fig. 5064, to carry 5 or 6 tons and weighing about 1¾ to 2 tons when empty, are usually more economical than double bogie trucks of greater weight and carrying capacity because, for intermediate traffic, it is frequently inconvenient to load large trucks to nearly their full capacity and thus cause haulage of unnecessary non-paying load. Double bogie trucks will, however, be preferable for haulage between terminals and for through traffic on all lines.

Passenger carriages, on the other hand, should be mounted on double bogies in order to obtain the length required to provide for the comfortable accommodation of a maximum number of passengers, with the flexibility necessary for travelling at high speed over curves without distorting the road.

CARRYING CAPACITIES OF TRAINS ON NARROW GAUGE RAILWAYS.

The following remarks are intended to epitomise the results obtained with locomotives or different gauges, types and weights, and rails of the minimum weights specified.

Unfortunately narrow gauge lines are rarely constructed with the care bestowed on main lines of normal (4-ft. 8½-in. or métre) gauge, and allowance has been made for this contingency in preparing the tables relating to the approximate hauling power, so that, on a well made line, the hauling power may be expected to exceed that indicated in the tables.

Heavier rails than those specified will carry more powerful locomotives, thus: 200 tons are hauled on the level on 1-ft. 6-in. gauge with 28-lbs. rails, and 480 tons on a 2-ft. gauge with rails 36-lbs. per yard, and proportionate loads on gradients. A 3-ft. gauge with rails weighing 50-lbs per yard will carry an engine with 16-in. cylinders capable of hauling 950 tons.

CARRYING CAPACITY IN RELATION TO WEIGHT AND GAUGE OF RAILS.

Gauge of rails ... ... inches	18	24	30	36
Minimum weight rails ... ... lbs. per yard	20	28	30	42
Carrying capacity on level ... ... tons.	90	200	340	650
,, ,, 1 in 100 ... ... ,,	35	70	110	210
,, ,, 1 in 50 ... ... ,,	20	40	60	125
,, ,, 1 in 25 ... ... ,,	12	20	30	65
Mean speed, miles per hour	10-12	12-15	15-20	25-30

18 inches gauge (and 20 inches) are frequently useful in factories, quarries, and for temporary service where exceptionally sharp curves cannot conveniently be avoided.

24 inches gauge (60 centimetres) adopted for the Festiniog Railway, has been so successful that it has been largely employed for other lines, especially in mountainous districts.

30 inches gauge has been, and will certainly continue to be, largely used on account of its large carrying capacity and accommodation for passengers, relatively with the total cost of the line.

36 inches gauge is that adopted for the Irish Light Railways and other lines, and very generally used by contractors in this and other countries.

4-ft. 8½-in. and Metre Gauge —The prices of Locomotives and Rolling Stock do not differ materially from those given further on, but as indicated at page, 3 the cost of rolling stock suitable for any given permanent way, cannot be estimated without the usual specification supplied by the engineer or by the builder.

Orders for locomotives to work on an existing railway (unless the type of engine, size of cylinders and gauge of rails are specified) should be accompanied by the undernamed details :—

Gauge of railway, *i.e.* distance between heads of rails.
Weight of rails and distance between sleepers.
Distance to be travelled without taking in fuel or water.
Gradient and length of steepest incline and radius of sharpest curve.
Maximum weight of train to be hauled, including rolling stock.
Gradient (if any) on which the engine must start with load.

If advice on construction is desired and cannot be obtained locally, data with reference to the last-named detalls must be furnished, together with accurate information relating to physical conditions, the cost and quality of timber, masonry and labour connected therewith, the extent and character of traffic, and such other details as will assist in preparing designs and approximate estimates for the necessary plant and accessories.

For tropical countries, plantation and other work, it is sometimes desirable to provide extra protection for the driver, spark arresting chimney, special ashpan, &c. The extra cost of these items ranges from £15 to £40.

Cow-catchers.—The extra cost of these is £10 to £20 per engine.

Fuel.—The engines referred to in the following pages are adapted for firing with either coal or wood, but the kind of fuel to be used should be stated.

Oil-firing.—Any of the engines can be fitted with the apparatus necessary for working with liquid fuel at an extra cost of about 5 per cent.

ENGINES FOR TEMPORARY ROADS.—The following tables relating to four and six wheel coupled engines furnish reliable general information with reference to the duty obtainable on temporary roads, the rails being not less than the weights specified for the respective sizes of engines.

GAUGES OF SMALL RAILWAYS.—The purposes the line has to serve and the local conditions are, of course, matters for primary consideration, but—as a rule—16, 18, and 20 inches gauge, with rails 10 to 14 lbs. per yard, are most suitable for manual haulage, 20 to 24 inches gauge for animal traction, and 30 inches gauge, with rails weighing 14 to 20 lbs. per yard, for locomotive traction, but—as is well known—the heavier rail is preferable even for the narrower gauges.

NARROW GAUGE LOCOMOTIVES.—The engravings indicate the general design of the leading types of Locomotives, but may not accurately represent the most recent modifications and improvements.

The following tables give the principal dimensions, hauling power, approximate prices, etc. and the kind and quality of materials used in the construction of the engines are as follows :

Boiler.—The shell and external fire-box are built of mild steel plates, double rivetted in longitudinal seams. The internal fire-box is of copper, with copper stays ⅞-inch diameter and about 4-inches pitch between it and the fire-box shell, and the tubes are of brass, solid drawn.

The fittings include Ramsbottom safety valve with lever and spring, fusible plug in fire-box, dial pressure gauge whistle, two injectors, and all furnace and exhaust fittings, and solid drawn copper tubes for steam and feed water connections.

The ordinary working pressure is 140-lbs. per square inch, and the boiler is tested by hydraulic pressure to 240-lbs. per square inch.

The frames are of mild steel, with cross stays and buffers and draw gear are fitted to the end frames.

The wheels with weldless steel tyres are forced on the steel axles by hydraulic pressure.

The axle boxes suitable for lubrication with oil or grease, are fitted with heavy brass bearings, horn blocks, and laminated steel springs.

The brake is worked by screw controlled from the driver's foot-plate.

Engines.—The cylinders are of close grained cylinder metal and fitted with cast-iron piston and cast-iron packing rings, waste water cocks worked by lever and handle from the foot-plate; the valve motion is of improved type, accurately fitted and case-hardened, and the reversing lever on the foot-plate is held in position by a sector and spring catch.

The connecting rods are of mild steel with heavy gun-metal ends adjustable for wear.

A coal bunker of maximum capacity is provided and an awning or cab can be fixed to shelter the driver.

Tools are provided for firing, and a lock-up box containing a complete set of spanners, hammer, spare gauge glass, tube brush and two oil cans.

Finish, test, etc —The parts are, as far as possible interchangeable and after the engine has been tested in steam, it is carefully painted, lined in and varnished.

DUTY OF ENGINES.—In preparing the following tables it has been assumed that a pressure of not less than 130-lbs. per square inch will be maintained in the boiler which will give about 100-lbs. in the cylinders.

Engines starting on an incline should not be expected to haul more than about 65 per cent. of the load specified in the tables.

The prices of locomotives, rolling stock, etc. are based on the normal cost of materials and labour, and on standard designs and proportions. Any deviation from these naturally affect prices.

APPROXIMATE DETAILS OF LOCOMOTIVES, FOUR WHEELS COUPLED.

Minimum weight of rails per yard, lbs.	12	14	16	18	20	22	25
Diameter of cylinders ... inches.	4	4½	5	5½	6	6½	7
Weight of engine in working order, tons	2¾	3½	4	5	5½	6¼	7
Tractive power ... ... lbs.	710	900	1245	1500	1800	2170	2450
Normal speed per hour ... miles	6-10	6-12	6-12	8-12	8-12	10-14	10-14
Hauling power on level ... tons	26	37	45	60	90	115	150
,, ,, 1 in 100 ... ,,	13	20	25	31	36	40	50
,, ,, 1 in 40 ... ,,	6	9	12	15	18	22	25
,, ,, 1 in 25 ... ,,	4	5½	7½	9	12	14	16
Minimum radius of curve ... feet	25	30	35	40	40	45	45
Price with copper fire box and tubes	£300	£330	£350	£400	£450	£500	£525
,, steel ,, ,,	£285	£310	£325	£372	£420	£467	£490
Weight of engine empty ... tons	2	2½	3	3¾	4¼	4¾	5½

APPROXIMATE DETAILS OF LOCOMOTIVES, FOUR WHEELS COUPLED—*Continued.*

Minimum weight of rails per yard lbs.	30	33	36	40	45	50	55
Diameter of cylinders ... inches	8	9	10	11	12	13	14
Weight of engine in working order tons	7¼	8½	10¼	11¾	13¼	14	16
Tractive power ... ... lbs.	3200	4000	5000	6000	7200	8450	9330
Normal speed per hour ... miles	12-18	12-20	15-20	15-20	18-25	18-25	20-30
Hauling power on level ... tons	200	250	340	420	500	575	650
,, ,, 1 in 100 ,,	70	85	110	130	160	190	210
,, ,, 1 in 40 ,,	35	43	53	65	80	95	105
,, ,, 1 in 25 ,,	20	25	34	40	50	60	67
Minimum radius of curve... feet	50	55	60	65	70	80	90
Price with copper fire-box and tubes	£625	£725	£800	£900	£1000	£1070	£1150
Price with steel fire-box and tubes ...	£585	£678	£745	£835	£925	£990	£1050
Weight of engine empty ... tons	7¼	8½	10½	11¾	13¼	14	16

The cost of packing for shipment and delivery f.o.b. is usually 5 per cent.

SIX-WHEEL COUPLED ENGINES.—The leading details are given in the following tables, and those relating to the speed and haulage power of engines, with cylinders of the same diameter, will be found in the preceding tables.

It will be seen that a lighter section of rail is admissible for six-wheel than for four-wheel engines of equal power and speed.

APPROXIMATE DETAILS OF LOCOMOTIVES, SIX-WHEEL COUPLED.

Minimum weight of rails per yard...	lbs.	14	16	18	20	22	25
Diameter of Cylinders	inches	5	5½	6	7	7½	8
Weight of Engine in working order	tons	4¾	5¾	6¼	8	9	10½
Mimimum radius of curve ...	feet	70	80	80	90	100	100
Price with Copper Fire-box and Tubes	...	£400	£450	£520	£600	£640	£675
,, Steel ,, ,,	...	£375	£422	£490	£565	£603	£635
Weight of Engine empty ...	tons	3¾	4½	5	6¼	7	8

APPROXIMATE DETAILS OF LOCOMOTIVES, SIX-WHEEL COUPLED—*continued.*

Minimum weight of rails per yard...	lbs.	28	30	33	36	40	45
Diameter of Cylinders	inches	9	10	11	12	13	14
Weight of Engine in working order	tons	12½	14¾	16¾	19	20½	23
Minimum radius of curve ...	feet	110	120	130	140	160	180
Price with Copper Fire-box and Tubes	...	£780	£865	£995	£1200	£1300	£1400
,, Steel ,, ,,	...	£733	£810	£930	£1125	£1215	£1300
Weight of Engine empty ...	...	9¾	11¾	13¼	15	16	18

The cost of packing for shipment and delivery f.o.b. is usually 5 per cent.

SADDLE TANK LOCOMOTIVE SIX WHEELS COUPLED, with copper fire-box and brass tubes, are built for any gauge and are suitable for service on colliery or branch lines, iron and other works.

DETAILS OF SIX-WHEEL COUPLED LOCOMOTIVES.

Diameter of cylinders ...	inches	10	11	12	13	14	15	16
Will haul on level ...	tons	350	420	525	600	725	800	950
,, ,, 1 in 100 ...	,,	120	135	170	200	220	260	325
,, ,, 1 in 50 ..	,,	66	75	95	110	130	145	170
,, ,, 1 in 25 ...	,,	36	42	52	64	70	83	105
Price of engine	...	£885	£1000	£1200	£1300	£1400	£1500	£1600
Weight in working order ..	tons	16	17½	21	24	26	27	30
Minimum weight of rails per yard, lbs.		33	35	40	45	48	50	55

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

TENDER ENGINE FOR NARROW GAUGE.—This engine (not illustrated) has four wheels coupled and leading four-wheel bogie, copper fire-box and brass tubes, extended smoke box, large fire-box and heating surface, spark arrester, etc. and is employed principally for passenger and mixed traffic. If with cow-catcher, the extra cost is £15 to £20.

DETAILS OF TENDER ENGINES.

Diameter of cylinders ..	inches	8	9	10	12	14
Normal speed per hour ...	miles	16	18	22	25	30
Will haul on level	tons	150	220	280	440	600
,, ,, 1 in 100 ...	,,	65	80	100	150	190
,, ,, 1 in 50 ...	,,	36	46	60	85	120
,, ,, 1 in 25 ...	,,	19	23	32	46	63
Price of engine	...	£900	£1150	£1250	£1500	£1800
Weight in working order ...	tons	10¾	13	15	19½	23½
Minimum weight of rails per yard	lbs.	22	25	28	33	36

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

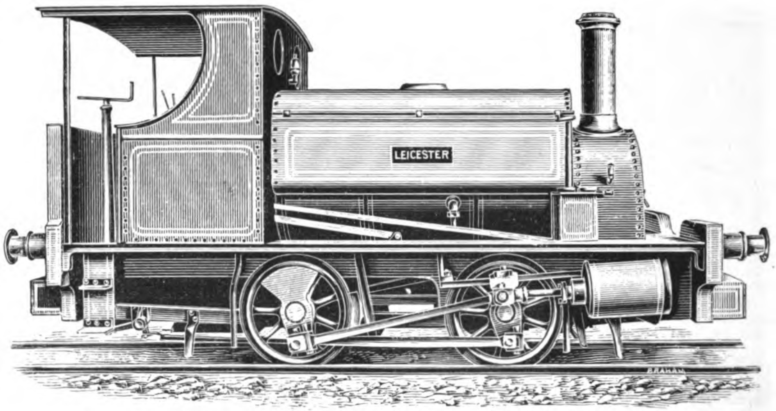


FIG. 5060.

SADDLE TANK FOUR-WHEEL LOCOMOTIVE.—The engraving, Fig. 5060, illustrates an engine for 4-ft. $8\frac{1}{2}$-in. gauge, with copper fire box and brass tubes, but this type is made for any gauge and is much used by contractors, also for collieries, quarries, iron works, etc.

The weight is well distributed and the engine runs steadily over rough road and sharp curves.

For specification see pages 92 and 93.

DETAILS OF FOUR-WHEEL COUPLED LOCOMOTIVES, FIG. 5060.

Diameter of cylinders ... ... inches	8	9	10	12	13	14
Will haul on level ... ... tons	200	250	330	480	570	650
,, 1 in 100 ... ... ,,	70	85	110	160	190	210
,, 1 in 50 ... ... ,,	39	49	62	93	105	127
,, 1 in 25 .. ... ,,	20	25	34	50	60	67
Price of engine	£650	£750	£825	£1000	£1100	£1200
Weight in working order ... ... tons	10	12	$14\frac{1}{2}$	18	20	23
Minimum weight of rails per yard ... lbs.	30	33	36	44	50	55

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

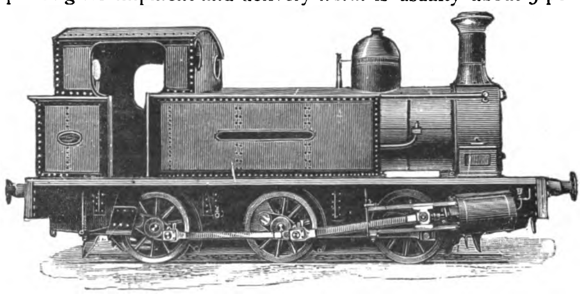


FIG. 5061.

SIDE TANK LOCOMOTIVE WITH BOGIE.—The subjoined details relate to engines with four wheels coupled and four wheel leading bogie, compensating beam, copper fire-box adapted for burning wood as fuel, brass tubes, spark arrester, &c.

These engines are suitable for passenger and goods traffic on branch or plantation lines of 2 feet to 3 feet 6 inches gauge, the bogie and compensating beam being of great advantage when running over rough roads and sharp curves. For notes on duty of engines, see page 91. For specification, see pages 92 and 93.

Side Tank Locomotive with Bogie, Fig. 5061.

Diameter of cylinders	inches	8	9	10
Normal speed per hour	miles	15	15	18
Will haul on level	tons	190	240	300
,, 1 in 100	,,	70	85	110
,, 1 in 50	,,	39	49	62
,, 1 in 25	,,	20	25	34
Price of engine	...	£700	£820	£915
Weight in working order	tons	11	13½	15
Minimum weight of rails per yard	lb.	25	28	30

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

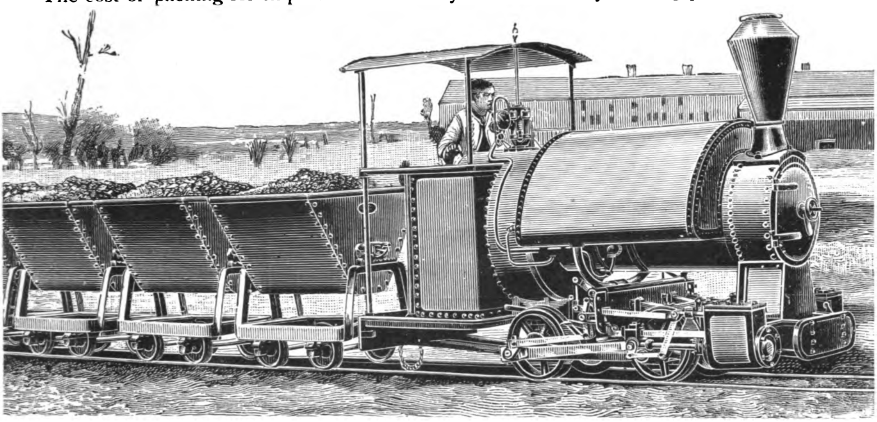


Fig. 5062.

SADDLE TANK LOCOMOTIVES FOR LIGHT TEMPORARY RAILWAYS.—Fig. 5062 represents a type of engine specially designed to work on light narrow gauge temporary roads, with curves and gradients to suit the local conditions and laid with little regard to a solid road bed ; it is low in first cost and equally so in cost of maintenance.

To attain these results, all unnecessary complications are eliminated, the working parts have large margins of strength, and are, as far as possible outside the frames to be completely accessible ; the fire-box is so arranged that it can (if necessary) be renewed in one day.

The saving in cost and time effected by using light engines and portable railway is well recognised, and the road is so easily and quickly taken up or re-laid, that with a little spare road, alterations are made in the existing track, or a new section laid, without appreciable interference with existing operations. The subjoined table gives the gauge of line and the minimum weight of rails suitable for each size of engine ; the prices of railway material will be found at pages 104 to 108.

The trucks are of the type Fig. 5071.

Details of Saddle Tank Locomotives, Fig. 5062.

Diameter of cylinders ...	inches	4½	5	6	7	8
Gauges of line	,,	18 to 22	18 to 24	18 to 30	24 to 36	24 to 36
Minimum weight of rails per yard	lbs.	14	14	18	24	28
Will haul on level	tons.	37	45	75	130	175
,, 1 in 100 ...	,,	20	25	36	50	65
,, 1 in 50 ...	,,	9	12	18	25	35
,, 1 in 25 ...	,,	5½	7½	12	16	20
Price of engine	...	£290	£325	£390	£475	£550
Weight in working order ...	tons	3½	4	5½	7	8¾

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

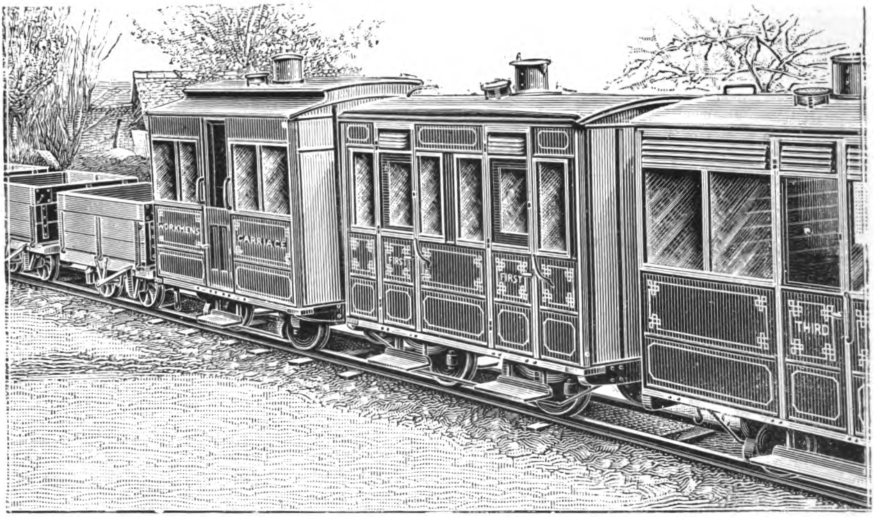


Fig. 5063.

PASSENGER CARRIAGES.—Fig. 5063 represents useful types of First, Third and Workmen's Carriages with all usual fittings, for narrow gauge mixed traffic.

The first class carriage is seated for 12 passengers, and costs about £160

The third class and workmen's carriages are seated for 16 passengers and costs about £120

Composite carriage (not illustrated) to seat 12 first class passengers, 16 second, and 8 third class, costs about £470

If with vacuum brake about £500

The carriage is about 31 feet long, and is fitted with two four-wheel swivelling bogies, central buffers with draw hooks and all usual accessories.

For approximate prices of trucks see pages 98 to 103, and for rails, etc. pages 104 to IC7.

The cost of packing is largely influenced by the nature of the packing required, but will probably be about 5 per cent.

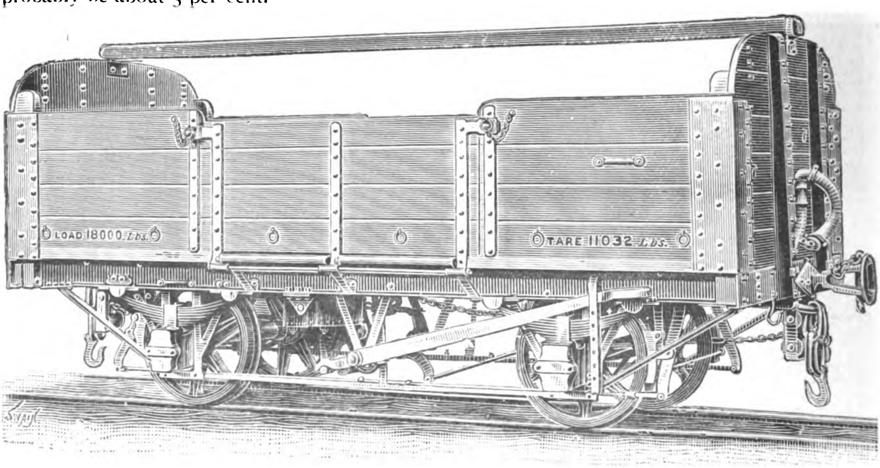


Fig. 5064.

OPEN GOODS OR SHEEP WAGONS have steel under-frames, four steel-tyred wheels, hand lever brake, and all accessories for main line traffic.

The cost, if fitted with vacuum brake, is given below.

PRICES OF OPEN GOODS TRUCKS, Fig. 5064.

Gauge of line	2-ft. 6-in.	3 feet	3-ft. 6-in.
Length of wagon	13-ft. 6-in.	15 feet	16-ft. 7-in.
Width of wagon	5-ft. 10-in.	6-ft. 9-in.	7-ft. 3-in.
Depth of wagon	4-ft. 4-in.	4-ft. 4-in.	4-ft. 4-in.
Diameter of wheels	24 inches	30 inches	33 inches
Wheel-base	5-ft. 6-in.	8-ft. 6-in.	9 feet
Price of wagon	£77	£81	£84
,, ,, with vacuum brake ...	£102	£106	£109

BALLAST OR LOW SIDE TRUCKS constructed as above illustrated and described and of the same dimensions, excepting that the depth is 1-ft. 6-in., can be obtained at (approximately) the undernamed prices.

PRICES OF BALLAST OR LOW SIDE TRUCKS.

Gauge of line	2-ft. 6-in.	3 feet	3-ft. 6-in.
Price of truck	£59	£62	£65

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

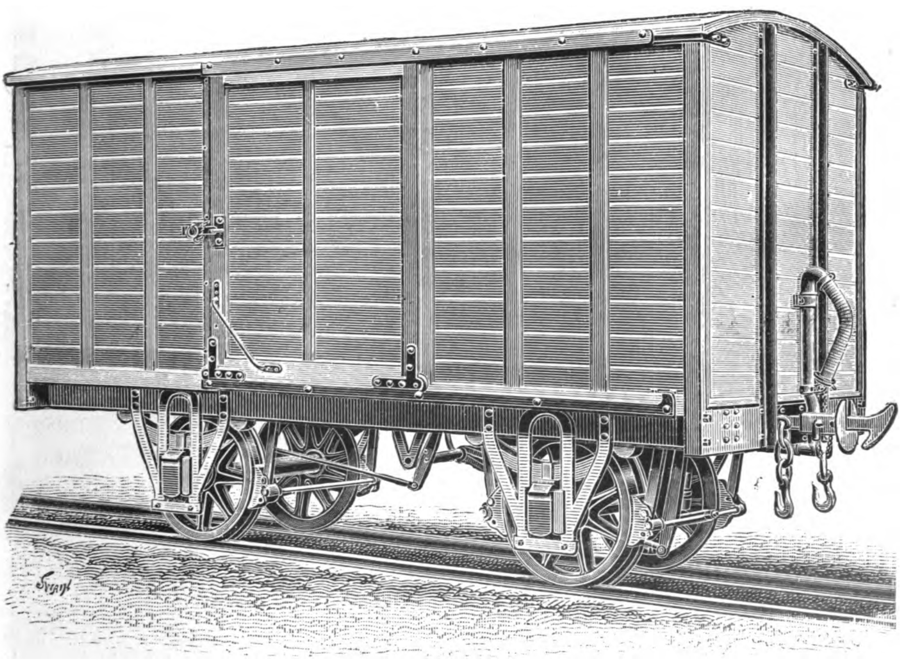


Fig. 5065.

COVERED GOODS WAGON, of the type Fig. 5065, is constructed with steel underframes and mounted on steel tyred wheels, laminated springs and steel axles, with axle boxes for oil or grease, and are complete with all usual fittings, as illustrated.

PRICES OF COVERED GOODS WAGONS, FIG. 5065.

Gauge of line	2-ft. 6-in.	3-ft.	3-ft. 6-in.
Length of wagon	13-ft. 6-in.	15-ft.	16-ft. 7-in.
Width of wagon	5-ft. 10-in.	6-ft. 9-in.	7-ft. 3-in.
Height of wagon inside	6-ft. 6-in.	6-ft. 6-in.	6-ft. 6-in.
Diameter of wheels	24-in.	30-in.	33-in.
Wheelbase	5-ft. 6-in.	8-ft. 6-in.	9-ft.
Price of wagon	£76	£79	£82
Price of wagon with vacuum brake ...	£101	£104	£107

COVERED MEAT or MILK VAN (not illustrated), with timber under-frames and steel tyred wheels 24-in. diameter and laminated springs, or chilled wheels and spiral springs, the axle boxes suitable for oil or grease.

PRICES OF COVERED MEAT OR MILK VANS.

Length of van ... ... feet	10	14	18
Price with laminated springs, etc.	£55	£61	£92
,, spiral ,, ...	£45	£60	£80

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

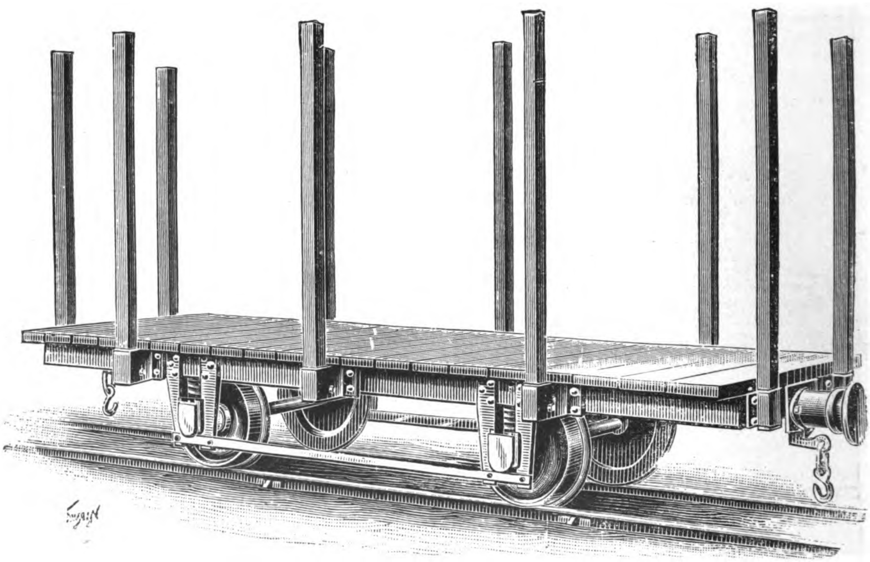


Fig. 5066.

PLATFORM WAGON Fig. 5066.—Trucks of this useful type for carrying cane and other plantation produce, bales, casks, stone, etc. are built of iron or timber, as preferred, and are fitted with ordinary bearings and without springs, or they can be supplied with any of the accessories mentioned in the following table. They are constructed to carry almost any weight, and the prices of those in general demand will be found below; also the extra cost of a platform at one end of the truck with column and brake to act on four wheels.

For carrying timber, the truck can be fitted with a swivelling cradle, to be used occasionally for carrying logs, as shown in Fig. 5067.

PRICES OF PLATFORM WAGONS Fig. 5066.

Length of wagon ... ... feet	5	6	7	8	9	10
Carrying capacity ... ... tons	$\frac{3}{4}$	$1\frac{1}{4}$	2	$2\frac{1}{3}$	$2\frac{1}{2}$	3
Price with fixed bearings up to 20-in gauge.	£5 2	£6 8	£7 18	£9 6	£10 0	£10 10
,, ,, ,, 30-in. ,,	£5 8	£6 15	£8 5	£9 15	£10 10	£11 5
,, ,, ,, 3-ft. 6-in. ,,	£5 12	£7 0	£8 10	£10 5	£11 0	£11 15
Extra for grease boxes and brasses ...	£0 6	£0 7	£0 8	£0 8	£0 9	£0 9
,, horn plates and springs ...	£1 0	£1 5	£1 10	£1 15	£2 0	£2 5
,, central buffer and draw hook ...	£1 15	£2 2	£2 2	£2 5	£2 5	£2 5
,, platform and brake	£2 0	£2 14	£3 9	£4 3	£4 10	£4 15

The cost packing for shipment and delivery f.o.b. is 5 per cent.

PLATFORM WAGONS FOR HEAVY LOADS can be supplied at the undernamed prices, the cost of accessories being as given in the preceeding table.

PRICES OF PLATFORM WAGONS FOR HEAVY LOADS.

Length of wagon ... ... feet	5	6	7	8	9	10
Carrying capacity ... ... tons	$1\frac{3}{4}$	$2\frac{1}{4}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$
Price with fixed bearings, up to 20-in. gauge	£6 3	£7 12	£9 10	£11 3	£12	£12 12
,, ,, 30-in. ,,	£6 10	£8 2	£9 18	£11 14	£12 12	£13 10
,, ,, 3-ft. 6-in. ,,	£6 15	£8 8	£10 4	£12 6	£13 4	£14 2
Carrying capacity ... ... tons	$2\frac{1}{4}$	$3\frac{1}{2}$	$4\frac{1}{2}$	$5\frac{1}{2}$	6	7
Price with fixed bearings, up to 20-in. gauge	£7 6	£8 16	£11 2	£13	£14	£14 15
,, ,, 30-in. ,,	£7 12	£9 9	£11 11	£13 13	£14 14	£15 5
,, ,, 3-ft. 6-in. ,,	£7 18	£9 16	£12 18	£14 7	£15 8	£16 9

The cost of packing for shipment and delivery f.o.b. is 5 per cent.

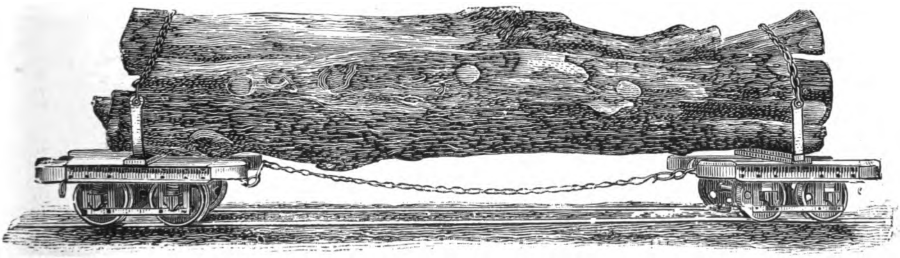


Fig. 5067.

TIMBER TRUCKS, Fig. 5067 consist of a pair of swivelling bogie carriages with steel frames, grease axle boxes, springs and swivelling cradles to carry logs or similar materials.

PRICES OF TIMBER CARRIAGES, FIG. 5067.

Carrying capacity ... ... tons	2	3	4
Price of pair of trucks	£17	£19	£21
,, ,, with brakes	£18 10	£21	£23

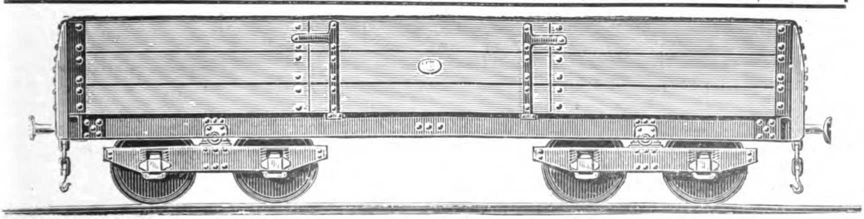


Fig. 5068.

NARROW GAUGE MAIN LINE GOODS WAGONS.—These trucks are mounted on two swivelling four wheel bogies, and fitted with door at each side to lower, buffers, draw-hooks, and safety chains.

The wagon illustrated is typical of all dimensions, this being for 30 inches gauge and carries 6 tons. The length is 15 feet, width 5 feet, and depth 2 feet.

High side covered goods (box cars) and cattle wagons have similar under-carriages and the approximate prices for them will be found below.

PRICES OF NARROW GAUGE DOUBLE BOGIE WAGONS.

Carrying capacity	tons	3	4	5	6½	8
Length of wagon	feet	10	12	14	16	18
Price of trucks as Fig.	...	£35	£40	£45	£55	£70
,, high side wagons		£38	£44	£50	£60	£76
,, covered and cattle wagons ..	...	£46	£52	£60	£72	£92
If with platform and brake	extra	£5	£6	£7	£8	£9

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

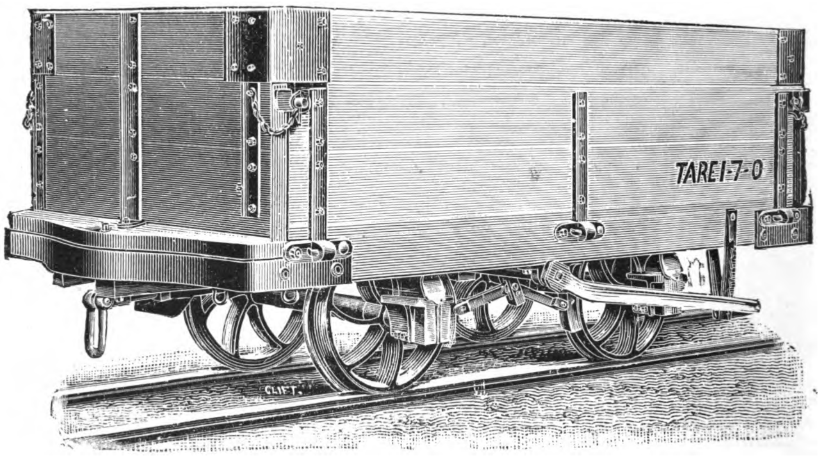


Fig. 5069.

OPEN GOODS OR MINERAL WAGONS, of the type Fig. 5069, are built for all gauges, 24-in. and upwards, with wood frame and hinged sides and draw gear. The wagon illustrated carries 4 tons on 30-in. gauge, the length is 9-ft. and the wheels are 18-in. diameter. The extra cost of lever brakes to two or four wheels will be found below.

PRICES OF OPEN GOODS WAGONS, FIG. 5069.

Carrying capacity	tons	2	3	4	5
Price of truck	...	£20	£25	£30	£34
Extra for brakes, two wheels	..	25/-	28/-	30/-	35/-
,, ,, four ,, ...	...	35/-	38/-	40/-	45/-

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

PLATFORM WAGONS (not illustrated) for carrying packages, bricks or other materials, with or without the ends are built of timber and fitted with grease axle boxes, but not mounted on springs.

If without ends, the cost is reduced about 10 per cent.

PRICES OF PLATFORM WAGONS.

Length of wagon ... ... feet	4	4½	5	5½	6
Carrying capacity ... ... cwt.	10	12	15	20	25
Price of truck for 20-inch gauge	£5 0	£5 10	£6 0	£6 15	£7 10
,, ,, 30-inch ,, ...	£5 15	£5 15	£6 10	£7 0	£8 0
,, ,, 3-ft. 6-in. ,, ...	...	...	£6 15	£7 10	£8 5

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

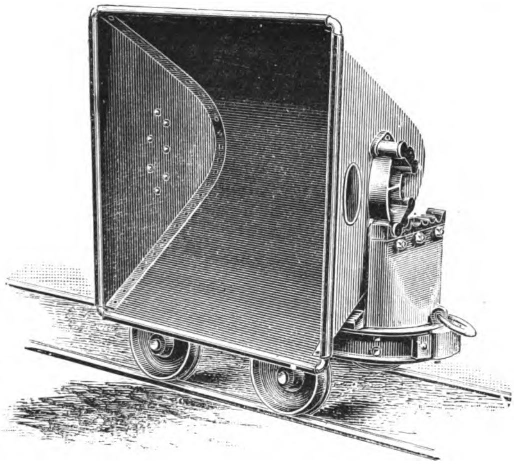


Fig. 5070.

STEEL TIPPING TRUCKS.—The following prices relate to narrow gauge trucks of the type illustrated by Fig. 5070, which are so largely used for the removal of earth, clay, gravel, sand and similar materials. The heavier type of truck, Fig. 5071, is preferable for carrying stone, minerals, &c.

In designing these trucks, care has been taken to provide maximum carrying capacity with minimum height for economy of labour in filling, also steadiness when running and stability when tipped. The size and angles of the truck body ensure free discharge, clear of the underframe, even of sticky materials.

PRICES OF STEEL END OR SIDE TIPPING TRUCKS, Fig. 5070.

Carrying capacity ... ...cubic feet	12½	15	20	27
Price of truck up to 20-in. gauge	£6 15	£7 5	£8	£9
,, ,, ,, 30-in. gauge	£7	£7 10	£8 5	£9 5
Extra for brake	12/-	13/-	15/-	20/-

PRICES OF STEEL ALL ROUND TIPPING TRUCKS.

Carrying capacity ... ...cubic feet	12½	15	20	27
Price of truck up to 20-in. gauge	£7 16	£8 7	£9 4	£10 7
,, ,, ,, 30-in. gauge	£8 1	£8 14	£9 11	£10 13
Extra for brake	12/-	13/-	15/-	20/-

The cost of packing for shipment and delivery f.o.b. is 5 per cent.

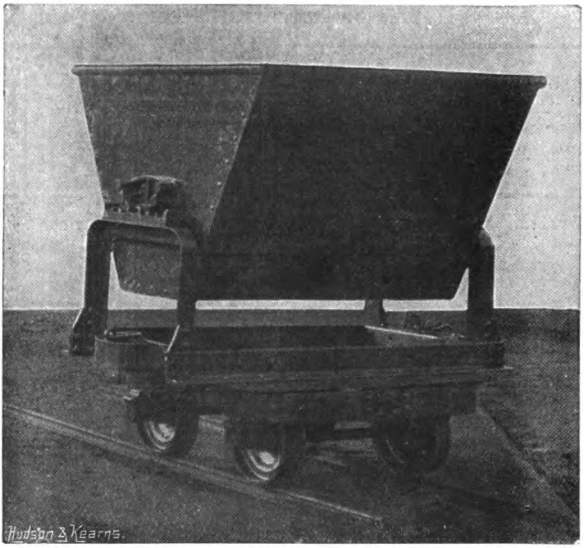


Fig. 5071

STRONG STEEL TIPPING TRUCKS, Fig. 5071, fulfil all the last-named conditions and are built of the heavier sections required for carrying minerals, stone, etc.

All round tipping trucks cost 15 per cent. more than end or side tipping trucks, thus one for 30-in. gauge to carry 40 cubic feet costs £18 8s. The cost of accessories will be as tabulated.

PRICES OF STRONG END AND SIDE TIPPING TRUCKS, FIG. 5071.

Carrying capacity ... cubic feet	27	40	60	70	80	100
,, ,, ... tons	1¼	2	3	3½	4	5
Price with fixed bearings up to 20-in. gauge	£11 3	£15 5	£21 10	£24	£26	£30
,, ,, ,, 30-in. ,,	£11 13	£16	£22 10	£25 5	£27 10	£32
,, ,, ,, 3-ft. 6-in. ,,	£12 5	£16 10	£23 15	£26 10	£29	£34
Extra for grease boxes and brasses ..	£0 7	£0 8	£0 9	£0 10	£0 11	£0 12
,, horn plates and springs ...	£1 10	£1 12	£2	£2 5	£2 10	£2 15
,, central buffer and draw gear ...	£2	£2 5	£2 10	£2 15	£3	£3 10
,, ratchet lever brake	£1 2	£1 8	£1 18	£2	£2 1	£2 5

PRICES OF END AND SIDE TIPPING TRUCKS FOR HEAVY LOADS.

Carrying capacity ... ...cubic feet	27	40	60	70	80	100
,, ,, ... tons	2	3	4	4¾	5½	6½
Price with fixed bearings up to 20-in. gauge	£13 8	£18 6	£25 16	£28 16	£31 5	£36
,, ,, ,, 30-in. ,,	£14	£19 4	£27	£30 6	£33	£38 10
,, ,, ,, 3-ft. 6-in. ,,	£14 5	£20	£28 10	£32	£35	£41

Carrying capacity ... ... tons	2¾	4	5	6	7	8
Price with fixed bearing up to 20-in. gauge	£16 15	£22 18	£32 5	£36	£39	£45
,, ,, 30-in. ,,	£17 10	£24	£33 15	£37 8	£41 5	£48
,, ,, 3-ft. 6-in. ,,	£18 10	£24 15	£35 15	£39 15	£43 10	£51

The cost of packing for shipment and delivery f.o.b. is 5 per cent.

MATERIALS FOR NARROW GAUGE RAILWAYS.

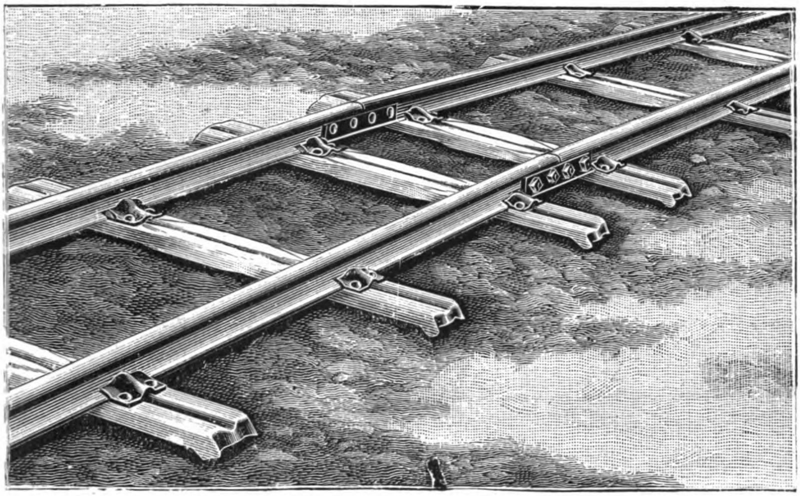


Fig. 5072.

RAILS AND SLEEPERS, Fig. 5072.—The rails are of steel, Vignolles section, and the corrugations of the sleeper prevent it from buckling; the depression between the corrugations serves to conduct rain water under the rail seats for discharge at the ends.

The sleepers are of mild steel, closed at the ends to retain the ballast at the points where it is most needed, and to prevent lateral movement in curves; each sleeper is dipped in anti-corrosive fluid.

The chairs which hold the rail in position are punched out of the solid; this dispenses with rivets and renders it impossible to lay the line out of gauge.

Rail connections.—The ends of the rails are connected by fish plates, bolts and nuts in the usual manner, by an automatic fish plate joint, or by joint sleepers with keys, as desired.

The approximate prices include rails and sleepers with any of the above-named joints, and are subject to fluctations in market prices. The prices are usually somewhat increased for quantities of less than about 1000 yards.

DETAILS OF STEEL RAILS AND SLEEPERS FOR LINES UP TO 20 INCHES GAUGE.

Weight of rails per yard ...	lbs.	10	12	14	16	18	20	22
Will carry on four wheels...	tons	2½	3¼	3¾	4¼	5	5½	6½
Price of materials per mile	...	£180	£220	£250	£275	£300	£350	£400
,, curved line per yard	...	3/6	4/-	4/6	5/-	5/6	6/-	6/4
Approximate weight per mile	tons	19¼	23	29	33¼	37	42	46
Weight of rails per yard ...	lbs.	25	28	30	33	36	40	45
Will carry on four wheels . .	tons	7½	8½	9½	11½	13½	16	18
Price of materials per mile	...	£450	£500	£520	£550	£590	£660	£750
,, curved line per yard	...	7/-	7/4	7/6	7/9	8/-	8/6	9/-
Approximate weight per mile	tons	53	58½	63	69¼	75½	85	98

DETAILS OF STEEL RAILS AND SLEEPERS FOR LINES 20 TO 30 INCHES GAUGE.

Weight of rails per yard ...	lbs.	10	12	14	16	18	20	22
Will carry on four wheels...	tons	2½	2¼	3¾	4¼	5	5½	6½
Price of materials per mile	...	£190	£230	£265	£290	£320	£370	£420
,, curved line per yard	...	3/9	4/3	4/9	5/3	5/9	6/3	6/8
Approximate weight per mile	tons	19¾	23¾	30½	35	39	44¼	48½
Weight of rails per yard ...	lbs.	25	28	30	33	36	40	45
Will carry on four wheels...	tons	7½	8½	9½	11½	13½	16	18
Price of materials per mile	...	£475	£526	£550	£580	£625	£700	£790
,, curved line per yard	...	7/4	7/8	7/10	8/2	8/6	9/-	9/6
Approximate weight per mile	tons	56	62	66¾	73	80	89	104

DETAILS OF STEEL RAILS AND SLEEPERS FOR LINES OF 30-IN. TO 3-FT. 6-IN. GAUGE.

Weight of rails per yard ...	lbs.	14	16	18	20	22	25
Will carry on four wheels ...	tons	3¾	4¼	5	5½	6½	7½
Price of materials per mile ...	...	£305	£345	£380	£420	£455	£515
,, curved line per yard ...	...	5/-	5/6	6/-	6/6	7/-	7/8
Approximate weight per mile ...	tons	32	37	41	47	51½	59½
Weight of rails per yard ...	lbs.	28	30	33	36	40	45
Will carry on four wheels ...	tons	8½	9½	11½	13½	16	18
Price of material per mile ...	...	£560	£585	£615	£665	£750	£845
,, curved line per yard ...	...	8/-	8/3	8/7	9/6	10/-	10/6
Approximate weight per mile ...	tons	65¾	71	78	84½	95	108

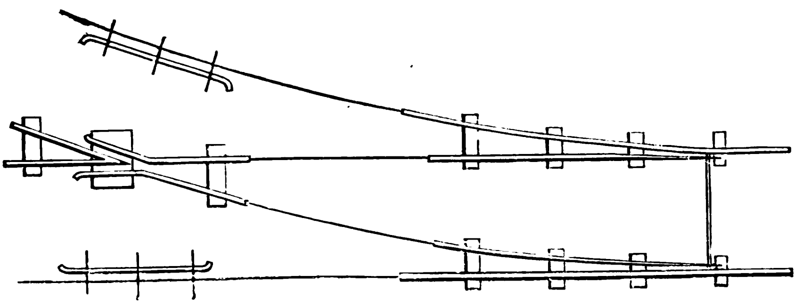


Fig. 5073.

STEEL POINTS AND CROSSINGS, Fig. 5073.—The diagram indicates a set of points and crossings, with stock and check rails, and without filling in pieces which are made right or left hand as required.

PRICES OF STEEL POINTS AND CROSSINGS Fig. 5073.

Weight of rails per yard ...	lbs.	10	12	14	16	18	20	22
Price per set up to 20-in. gauge	...	£2	£2 5	£2 10	£2 17	£3 3	£3 15	£4 10
,, ,, 20 to 30-in. gauge		£2	£2 5	£3	£3 10	£4	£4 10	£5 5
Weight of rails per yard ...	lbs.	25	28	30	33	36	40	45
Price per set up to 20-in. gauge	...	£5 10	£6	£6 8	£6 15	£7 5	£8	£9 10
,, ,, 20 to 30-in. gauge		£6	£7	£7 10	£8	£9	£10	£11

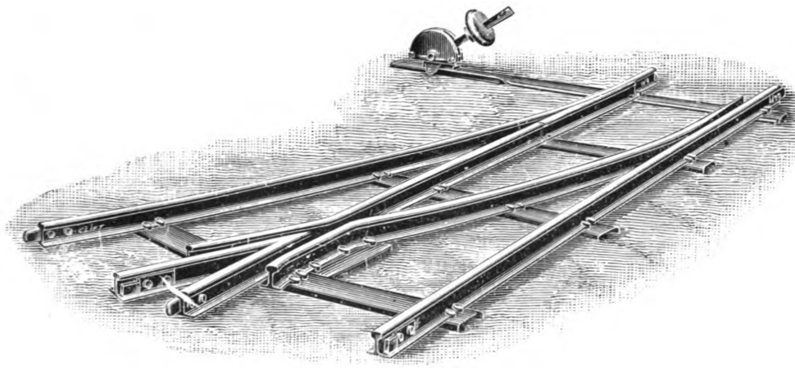


Fig. 5074.

STEEL SWITCHES.—Fig. 5074 represents a set of switches suitable for ordinary traffic, wth lever handle and counterweight. Many other combinations are made but they scarcely admit of being tabulated.

Switches of lighter type can be obtained, but those illustrated are generally preferred.

PRICES OF STEEL SWITCHES, FIG. 5074.

Weight of rails per yard ... lbs.	10	12	14	16	18	20	22
Price per set up to 20-in. gauge ...	£3 10	£4	£4 15	£5 10	£6	£7	£8 10
,, ,, 20 to 30-in. ,, ...	£4	£4 10	£5 10	£6 5	£7	£8 5	£9 10
Price of two-way switch, 20-in. gauge	£3 17	£4 8	£5 5	£6 1	£6 12	£7 14	£9 7
,, ,, 20 to 30-in. ,,	£4 8	£5	£6 1	£6 18	£7 14	£9 2	£10 10
Extra for lever and counterweight	15/-	16/-	18/-	19/-	21/-	22/-	25/-

Weight of rail per yard ... lbs.	25	28	30	33	36	40	45
Price per set up to 20-in. gauge ..	£10	£11	£11 15	£13	£14	£15 10	£17 10
,, 20 to 30-in. ,, ...	£11	£12 15	£13 10	£15 10	£17	£19	£21
Price of two-way switch, 20-in. gauge	£11	£11 2	£13	£14 6	£15 8	£17 1	£19 5
,, ,, 20 to 30-in. ,,	£12 2	£14 1	£14 17	£15 15	£17	£18 15	£21 4
Extra for lever and counterweight	£1 6	£1 10	£1 12	£2	£2 5	£2 10	£2 15

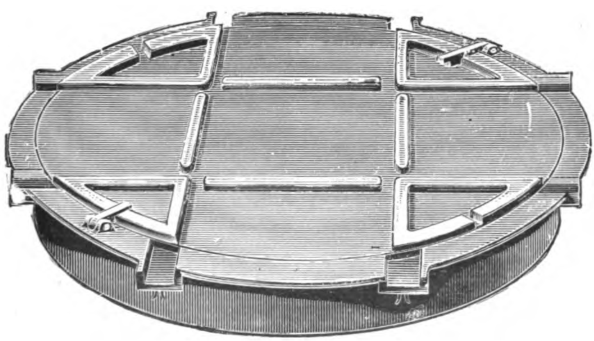


Fig. 5075.

TURNTABLES are built of any diameter and carrying capacity, and provided with rails of any weight or gauge required, but the following prices for a few sizes of turntables of the type, Fig. 5075 may be useful when estimating the approximate cost of equipments.

These turntables are made with cast or wrought iron casing, as illustrated, or the ironwork only is supplied ready for erection in a curb built in masonry or timber.

The flooring of chequered plate or timber is not included in the prices, but either can be provided at an extra cost of about 10 per cent.

PRICES OF TURNTABLES, FIG. 5075.

Diameter of table ... ... feet	5	5½	6	7	8	9	10
Carrying capacity ... ... tons	6	8	10	10	12	10	14
Price with curb	£21	£28	£34	£42	£53	£50	£74
,, without curb	£18	£24	£29	£36	£45	£42	£63
Diameter of table ... ... feet	12	12	14	16	18	20	20
Carrying capacity ... ... tons	14	20	15	15	20	12	20
Price with curb	£87	£117	£105	£120	£170	£126	£185
,, without curb	£72	£98	£87	£100	£137	£105	£153

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

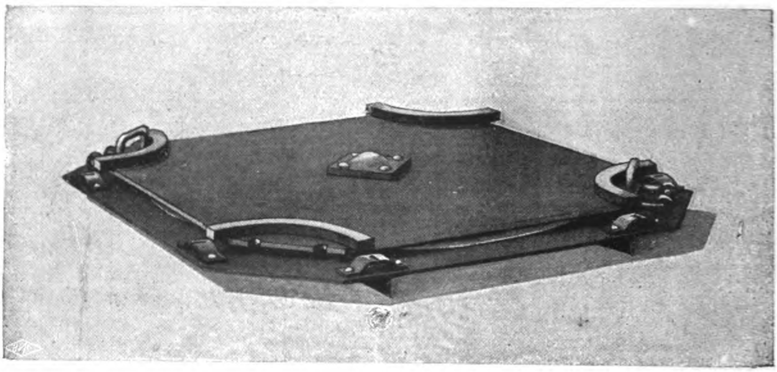


Fig. 5076.

SMALL TURNTABLES with single or cross roads are self-contained without curb for setting in brickwork, as illustrated by Fig. 5075.

PRICES OF TURNTABLES, Fig. 5076.

Diameter of table ... feet	3	3½	4	5	6	7	8
Carrying capacity ... tons	1	1½	2	4	5	6	6
Price of turntable with curb ...	£3	£4	£6 10	£12 5	£15 15	£20	£23 10
,, ,, without curb ...	£2 10	£3 10	£5 5	£10 5	£13 5	£17	£19 10

TIPPING PLATFORMS (not illustrated) are made fixed or portable, for discharging sugar cane at the mill, for unloading other products and materials and for transferring ore, coal, &c. from narrow gauge trucks to broad gauge wagons.

They are usually specially designed for the conditions to be fulfilled, but the cost is approximately as follows.

PRICES OF TIPPING PLATFORMS.

Gauge of rails...	Up to 20 inches	20 to 30 inches
Price of portable tip	£11	£12
,, fixed tip	£9	£10

TRUCK TIPPLERS of the type used about colliery and other heapsteads, and for completely emptying trucks carrying coal, chalk, clay, ore, &c.

PRICES OF TRUCK TIPPLERS.

Gauge of rails	Up to 20 inches	20 to 30 inches	30 to 36 inches
Price of tippler	£14	£15	£16

SIGNALS FOR LIGHT RAILWAYS of wrought iron lattice construction, about 25 feet high, are provided with lamp, revolving disc, ladder and fittings, including pull-over lever for working from the station platform.

The price for home signal is £36

The price for distant signal is £50

Ironwork and fittings for signals, to be attached to a timber post, consist of lamp, and spectacle, hand lever, ladder, and iron socket.

The price of ironwork, &c. for home signals is £12

The price for distant signals is £18

Pull-over lever, balanced arm, wire and pulleys for distant signal costs about ... £8

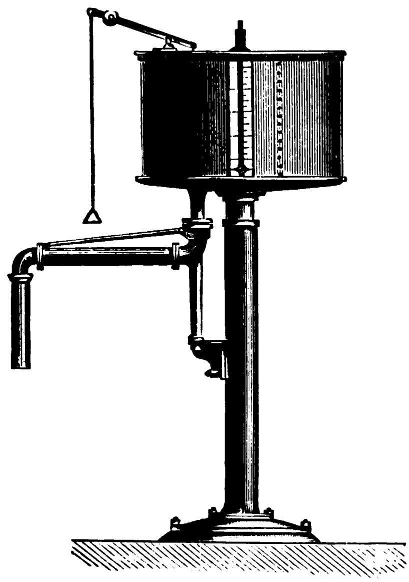


Fig. 5077.

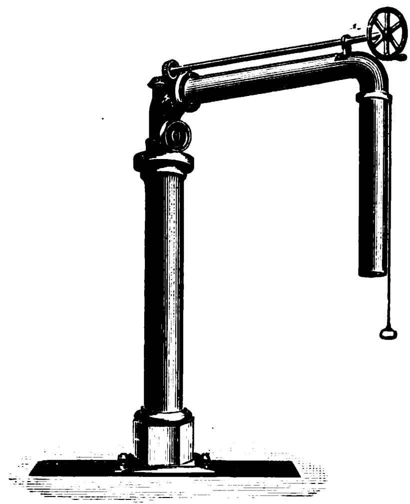


Fig. 5078.

WATER CRANE WITH TANK, Fig. 5077.—A pipe up the centre of the column conveys the water supply to the tank, and the swing arm is complete with valve, lever, float and gauge to indicate the level of water in the tank.

PRICES OF WATER CRANES WITH TANKS, FIG. 5077.

Capacity of tank .. .. gallons	1000	2000
Price of water crane	£70	£110

WATER CRANE WITH SWING ARM.—Fig. 5078 illustrates the type in use on main line railways and is fitted with copper arm and leather hose, main valve controlled by the driver, flanged bend and foundation bolts.

PRICES OF WATER CRANES, FIG. 5078.

Diameter of pipe ... ... inches	6	7	8
Price of water crane...	£45	£55	£65

WATER CRANE WITH COLUMN AND FIXED ARM (not illustrated) is provided with flexible hose, top bend and arm, flanged bend at base and foundation bolts.

PRICES OF WATER CRANES WITH FIXED ARMS.

Diameter of Pipe ... ... inches	5	6	7	8
Price of water crane	£30	£35	£40	£45

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

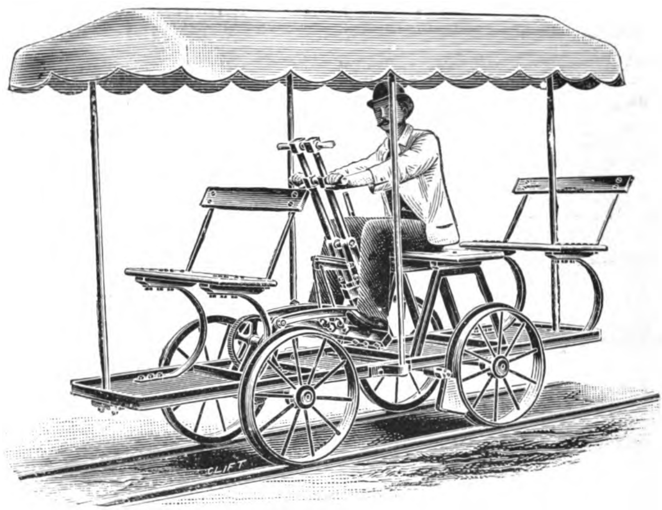


Fig. 5079.

INSPECTOR'S TROLLEY with steel frame, garden chair seats, levers for propulsion, stancheons and awning.

To seat	2	3	4	6
Price of trolley	£17	£21	£27	£45

CONTRACTORS' WAGONS, PLATELAYERS' TOOLS, TROLLIES, &c. are illustrated and described under their respective headings.

Wheels, axles and axle boxes.—The cost of these will be found at page 126 and 127.

Ironwork for wagons and trollies can be quickly obtained, provided that the necessary information, or sketches with figured dimensions are supplied.

RAILWAY STATION LIFTING EQUIPMENTS.—The cranes now illustrated are largely used on lines of normal gauge and are peculiarly suitable for narrow gauge traffic, as well as for saving time and labour in transferring goods at break of gauge.

PLATFORM OR SHED CRANES.—The engraving Fig. 5080 represents a crane which swings entirely round, and has appliances for "whipping" loads quickly up to 400 or 500 lbs., heavier weights being lifted by single or double purchase gear.

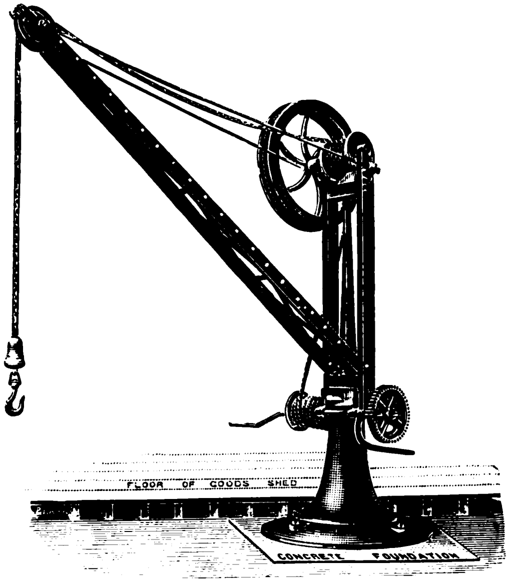


Fig. 5080

The area of the base is so large that expensive foundations are not required. Both radius and height of jib can be modified to suit circumstances.

PRICES OF PLATFORM CRANES, FIG. 5080.

Power of crane	tons	1	$1\frac{1}{2}$	2	3
Radius of jib	feet	12	$12\frac{1}{2}$	12	12
Price of crane complete		£45	£52	£60	£70

WHIP CRANES WITH TOP SUPPORT (not illustrated). The arrangement of lifting gear is similar to that shown in Fig. 5080 but the top and bottom of the mast are kept in position by steel pivots, the former being carried by a roof timber or other attachment.

PRICES OF WHIP CRANES WITH TOP SUPPORT.

Power of crane	tons	1	$1\frac{1}{2}$	2	3
Radius of jib	feet	10	11	12	12
Price of crane complete		£30	£35	£40	£55

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

FIXED YARD OR WHARF CRANES similar in arrangement to Fig. 5081, are built of all powers from 3 to 40 or 50 tons ; the radius of jib is modified to suit circumstances, but the standard proportions are those tabulated.

The centre post is of hammered scrap iron or steel, keyed in a massive foundation plate, and all sizes above 3 tons have turned roller path and slewing motion, as illustrated.

PRICES OF FIXED YARD CRANES.

Power of crane	tons	3	5	10	15	20
Radius of jib...	feet	14	15	18	18	20
Price of crane with steel jib		£95	£126	£266	£367	£525
Extra for gun metal bearings and caps		£7	£10	£14	£19	£23

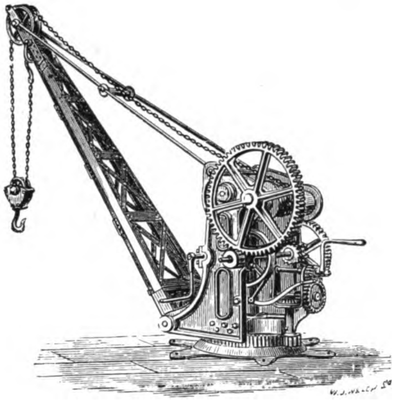


Fig. 5081.

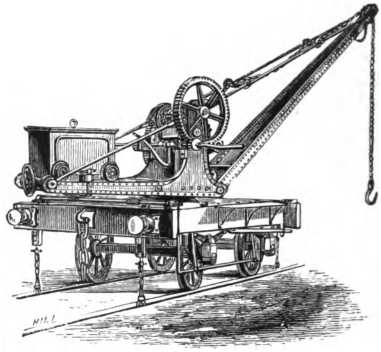


Fig. 5082.

PERMANENT WAY CRANES up to 5 or 7 tons power are carried on four wheels and those of larger power on six wheels, all being fitted with springs, axle boxes for oil or grease, buffers, spring draw gear, brake, and the accessories for travelling with rolling stock.

The jib is made to lower, the position of the counter weight box is adjustable by screw, and appliances are provided for holding it in position when travelling.

PRICES OF PERMANENT-WAY CRANES.

Power of crane ... ... tons	3	5	7	10	12
Radius of jib ... ... feet	13	14	15	15	16
Price of crane, complete	£290	£350	£410	£500	£560
Extra for slewing gear	£10	£12	£13	£16	£18

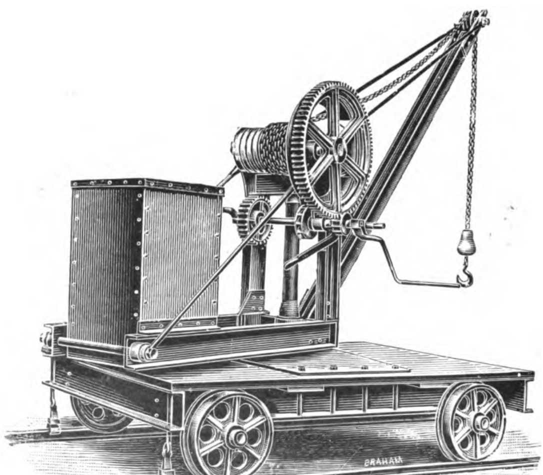


Fig. 5083.

PORTABLE CRANES.—Many cranes similar to that illustrated by Fig. 5083, have been made for light railways, for which, indeed, they were originally designed. The framework is principally of steel, and provision is made for the requisite stability, even when working on light narrow gauge tracks.

PRICES OF PORTABLE CRANES, FIG. 5083.

Power of crane ... tons	1	2	3	4	5	6
Radius of jib ... feet	9	9	10	10	11	12
Price of crane	£47	£62	£89	£107	£140	£160
Adjusting screw to balance box	£2	£2	£2	£3	£3	£3
Rail clips or under-girders ...	£2	£2	£3	£3	£4	£4

FIXED OR PORTABLE GOLIATH CRANES worked by hand, electric, or steam power, with metallic or timber frame, usually give satisfactory results where wagons can be marshalled on parallel lines of broad and narrow gauge. These are spanned by a goliath crane, constructed as indicated in Figs. 5008 or 5009, which commands the wagons on both roads and effects the transfer with minimum expenditure of power.

The rolling stock is so easily moved to a fixed crane that the travelling motion, which adds about 10 per cent to the cost of the crane, is rarely required.

PRICES OF FIXED HAND POWER GOLIATH CRANES.

Power of crane ... ... tons	5	10	15	20	25
Span ,, ... feet	30	30	30	30	30
Height ,, from rail level ... ... ,,	14	14	14	14	14
Price with iron frame	£250	£340	£435	£510	£627
,, timber frame	£220	£310	£400	£455	£550

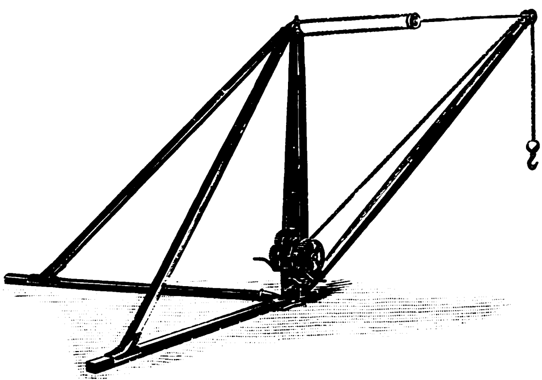


Fig. 5084.

DERRICK CRANES.—The great range covered, and the ease with which the radius of the jib is varied are frequently of great advantage in goods stations.

For transfer purposes the crane is usually placed between the broad and narrow gauge lines in a position which renders it available for delivering, for distribution or for transferring.

If greater length of jib is required it can be provided at an extra cost of about 1 per cent. per foot of extra length.

PRICES OF DERRICK CRANES, FIG. 5084.

Power of crane ... ... tons	2	3	4	5	7	10
Length of jib ... ... feet	40	40	40	40	40	40
Maximum radius ... ... ,,	32	32	32	32	32	32
Price of hand power crane	£54	£70	£85	£96	£132	£175
,, steam ,, ...	£188	£213	£247	£320	£400	£530

STEAM AND ELECTRIC CRANES to fulfil most of the conditions referred to in the preceding pages are illustrated and described elsewhere in this volume and in considerable detail in Section II.

TRANSFER OF GOODS AT BREAK OF GAUGE.—Arrangements for quickly and economically transferring materials to rolling stock of different gauges are, of course, very diversified, but one or other of the undernamed methods will probably be found suitable.

PARALLEL LINES.—One method whereby merchandise, coal, ore, etc. has been cheaply and quickly transferred consists in having parallel lines, one at a higher level than the other, with a shoot between the trucks. Since this arrangement was adopted the cost of tran-shipment has been reduced by one half, and the time, by three fourths of that previously required.

INTERMEDIATE TRACK.—Another arrangement which often answers every purpose consists in laying a narrow gauge track of the requisite length between the rails of the broad gauge line, so that the opening ends of trucks of both gauges can be brought close together, which admits of even heavy and bulky packages being easily transhipped.

But neither of the last mentioned arrangements will probably be quite so satisfactory as the mechanical appliances referred to in the foregoing pages.

ACCIDENT CRANES AND EQUIPMENTS.

ACCIDENT CRANES AND TRAINS.—Several circumstances, such as the length of line, sparseness (or otherwise) of population in its vicinity, the use of the crane for other purposes, and so forth, need to be taken into account, when the kind of crane and the completeness of equipment for an accident train is under consideration.

Equipments suitable for a short line, or for one passing through districts where assistance of all kinds is quickly at hand, will evidently be insufficient for a main line where the conditions are reversed, and where everything required for re-instating the road for traffic—including tools, labour, a supply of food, and even first-aid appliances and some comforts for those who have been injured—must be brought from a main station.

Types of cranes.—The earlier permanent-way cranes were usually of 5 or 10 tons power, worked by hand, and many of these are still required for innumerable purposes where plenty of labour is available and great speed is not essential; for engravings and descriptions of these see page 111 and pages 79 and 80, Section II.

The recent practice, however, is to provide steam cranes of 10, 15 or even 20 tons power, of the horizontal type illustrated by Figs. 5036 and 5085 (invented and patented by the writer) which afford the driver unimpeded view of his work, the engines and gear being so arranged that the crane is easily worked by one man. Cranes of vertical construction frequently require a "look-out" man, beside the driver, and are scarcely so convenient as those of the newer and improved design.

Relative advantages of hand and steam cranes. A permanent-way hand crane, costs about half as much as a steam crane of equal lifting power, and it can, of course, be worked by quite unskilled men.

A steam crane, on the other hand, driven by one man will get through far more work than can be done in the same time by 10 men working with hand-power cranes. The hand crane, therefore, is perfectly satisfactory where great speed is of little or no importance, the steam crane being essential when these conditions are reversed.

A steam crane of 15 tons power is usually equal to all work to be performed in connection with accident trains, and is probably the most convenient power and weight for that and the other duties mentioned further on.

Two, or more of these cranes can usually be employed, with advantage, at main stations, or at each of the terminal stations, and—the crane power being concentrated at any point where it is required--the time occupied in clearing and re-instating the line, even after a serious accident is greatly diminished. See also remarks at page 203 to 210 on "renewals."

The cranes being usually employed in the goods yards, repairing shops, or elsewhere, are instantly available for despatch with the vehicles forming the accident train.

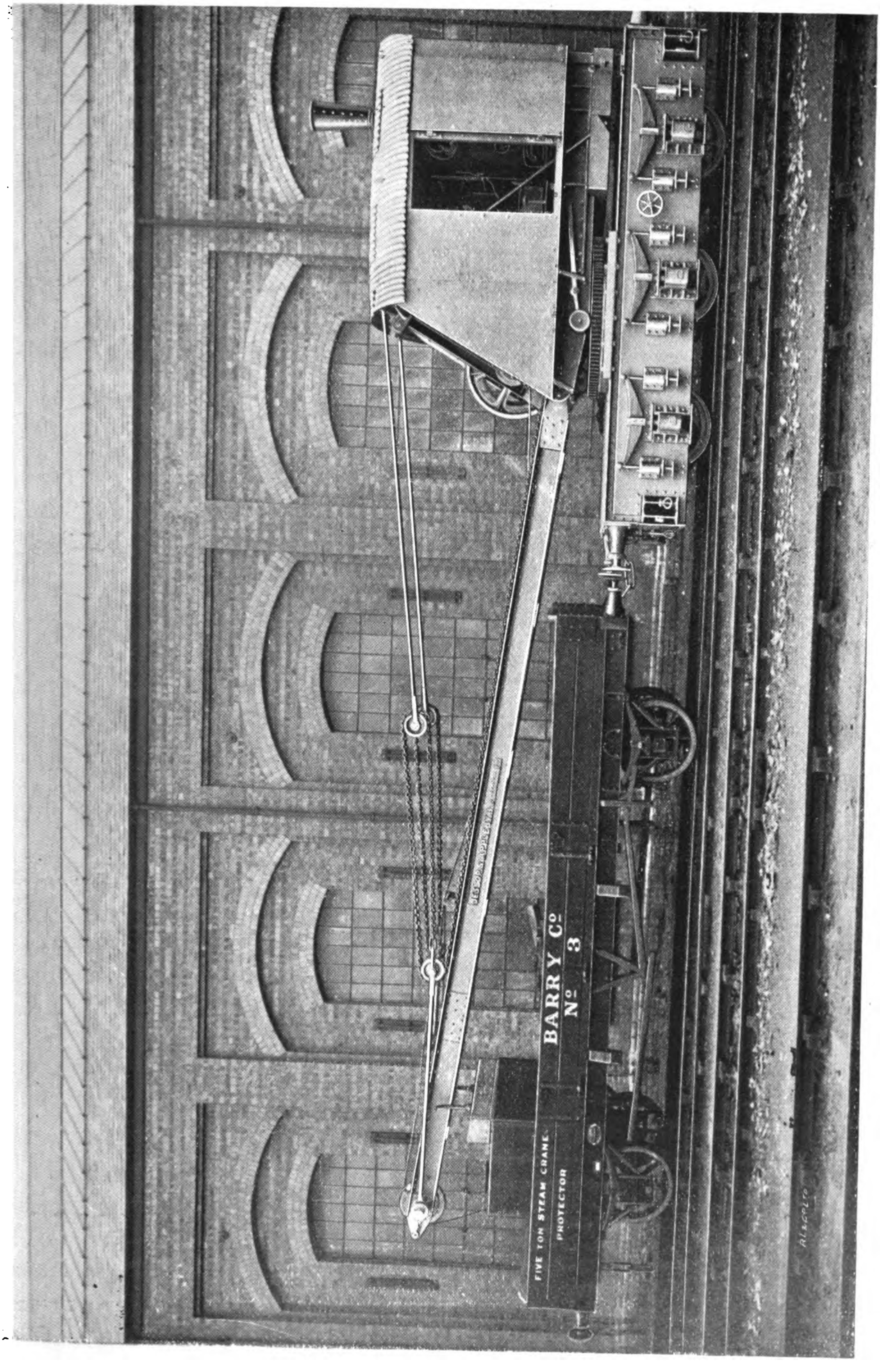


Fig. 5035.

Wagons, tools and accessories.—The following specification, adopted by an eminent Engineer for service on an important main line which he so ably controls, has been kindly placed at the writer's disposal, and—being much the most complete he has seen—it affords data for the selection of materials required for the equipment of accident trains suitable for lines, differing from this in extent and local conditions. The train consists of:—

A locomotive steam crane of 15 tons power, with gear to travel at a speed of 3 to 4 miles per hour, and with fittings for hauling trucks and for detaching the travelling motion, leaving the axles free when the crane is hauled by locomotive.

The radius of the jib is adjusted by steam power and the jib is lowered for travelling as indicated in the engraving. The undercarriage is complete with all fittings to correspond with other rolling stock, and the overall dimensions conform with the standards for vehicles.

A six-wheeled wagon (or "protector" truck), has falling sides and bolster for supporting the crane jib when travelling. This wagon also carries the tackle first required, as hereafter specified:—

A six-wheeled covered wagon ("Box car"), 30-feet long, has a compartment at one end for accomodating the staff, the rest of the wagon forming a tool van for the storage of tools and appliances specified below.

A six-wheeled permanent way wagon with folding sides, carrying a supply of rails, etc. for making up roads.

Equipment for articles in tool van:—

Two 30-tons lifting and traversing hydraulic jacks.
One 15-tons ,, ,, ,,
Two 20-tons lifting and traversing screw jacks.
Two 20-tons Hydraulic jacks.
Five 12-tons ,, ,,
One 5-tons ,, ,,
Two 3-tons screw jacks.
Two 6-tons and two 12-tons bottle jacks.
One jim crow.
Two pails.
One watering can.
Two plugging hammers.
One dozen hand lamps.
A complete set of side and tail lamps.
One dozen torch lamps and spare wicks for same.
Cans for lamp oil and petroleum.
A set of fitter's tools with appliances for disconnecting tenders and motions for engines.
One bench vice.
A set of gimlets and augers, from $\frac{1}{8}$-in. to 2-in.
Chisels, gouges, screw-drivers, carpenter's hammers, adze, axe, two long cross-cut saws, two hand saws, and a wheel gauge.
A rail gauge.
Two shifting spanners; a pair of strong cutting pliers.
Steel spanners from $\frac{3}{8}$-in. to $3\frac{1}{2}$-in.
Drifts $\frac{1}{2}$-in. to 1-in.
Engine following board.
Supply of asbestos for jointing.
Six portable seats.
Coal and oil bunkers under floor.

Locker on side of van:—

Fitted with writing desk, stationery, rule-book, time-tables, etc.

Locker on side of van with small drawers, containing:—

Cup leathers, syphon wire and wool, gauge-glasses, and washers for crane.
A 66-ft. steel tape.
Supply of flax and packing.
Supply of fog-signals and flags.
Supply of first-aid appliances.
Also wash basin, brush and comb, mirror, clothes brush, water lifter for filling crane tanks.

In compartment at end:—

Twelve portable seat cushions.

In locker under floor :—

Twelve shovels, two picks, rope and spun yarn.
Three sheave rope blocks for slewing engines, assisting crane, etc.
Nails, bolts, and wood screws.
24-ft. of $\frac{3}{4}$-in. hose for water lifter.

In protector wagon.

Three engine lifting bars and four 20-ft. lengths of $\frac{3}{4}$-in. dragging chain.
Two 20-ft. lengths of $\frac{1}{2}$-in. chain with hook at one end and ring at the other.
Two 20-ft. lengths of $\frac{5}{8}$-in. chain with hook and ring as above.
One 30-ft. length of $\frac{5}{8}$-in. chain.
One 30-ft. length of 1-in. chain.
One four-branch sling, $\frac{3}{4}$-in. link, 15-ft. long, for lifting wagons.
Two two-branch sling, 1-in. link, 15-ft. long, for lifting engines.
One two-branch sling, $\frac{7}{8}$-in. link, 15-ft. long, for lifting girders.
One two-branch sling, $\frac{5}{8}$-in. link, 15-ft. long.
One two-branch sling, $\frac{1}{2}$-in. link, 10-ft. long.
One Wells' portable light.
Four wagon ramps.
Four tender ramps.
Three single anchors.
Two transverse girders for blocking up crane.
One yoke for lifting carriages.
One yoke for lifting boilers.
A supply of hooks and links for dragging purposes.
Two large and two small pinch bars.
One axle clip for securing a broken axle.
A supply of engine and tender couplings.
Three grease boxes, timber packing, &c.
Three sheaves, 18-in. diameter, with large shackles and pins.
One dozen screw couplings.
One dog for lifting timber.

Two boxes at end of wagon containing :—

Two four-gallon cans of petroleum for torches, and 20-lbs. of tallow, the other being used for spare ropes.

In permanent-way wagon :—

Two rails, 19-feet long. A quantity of short pieces to make up lengths—21 or 24 feet—as required.

Cooking and other utensils in covered van :—

One circular stove	Two dozen enamelled drinking jugs
One copper boiler	One dozen enamelled soup basins
One coffee kettle and strainer	One dozen enamelled small plates
One tin coffee heater, with spout	One dozen tumblers
One boiling pan	One dozen glasses
One enamelled tea pot	Half dozen towels
One filter	Half dozen sponge cloths
One coffee mill	One dozen tin basins
One dozen breakfast knives	One coffee tin (14-lbs.)
One dozen breakfast forks	One sugar box (28-lbs.)
One dozen large spoons	One tin box opener
One dozen small spoons	One bar of soap

Provisions and Wines :—

18-gallon cask of stout	Tinned meats
One dozen whisky	Condensed milk
One bottle brandy	One dozen boxes sardines
One box of red herrings	14-lbs. coffee
56-lbs. cask Huntley & Palmer's luncheon biscuits	2-lbs. tea
One dozen cheeses	28-lbs. sugar

The approximate cost of an accident train, including the 15-tons locomotive steam crane, with protector truck, the permanent way wagon for rails etc. and the tool van with fittings and equipment, of tools and accessories, as specified, is about £4,000

The locomotive and permanent way materials being at hand in ordinary service, are not included in the foregoing estimate.

The crane and driver as already indicated are only temporarily diverted from their ordinary employment.

First-aid appliances.—The following specification of a more complete equipment than is usually provided may be useful as a reserve supply, or in case of a severe accident.

One set of Liston splints, one set Clive's leg splints, two sets of lined splints, one Lawrence cradle and splint, three dozen bandages each 2½ and 3 inch, two dozen triangular and one dozen finger bandages, 2-lbs. marine lint and 2-lbs. wool, 2-lbs. Alambroth wool in tins, 2-dozen yards gauze, medicine chest with 16-oz. bottles Carron oil, 10-oz. spirit ammonia, 16-oz. brandy, four india rubber tourniquets, one pair dressing and one pair spring forceps, housewife, fitted, lint scissors, two horn measures graduated, three pieces of sponge, six arm slings, three pairs of crutches, one dozen eye shades, box of safety pins, six enamelled dressing bowls, large box for sundries.

The total cost of this equipment is about £10

To the foregoing may be added two stretchers about 70/- each, carrying chair about 60/-, two air-beds about £6 and six pillows about 2/6 each.

Another epuipment of first-aid appliances consists of a haversack containing a useful supply of first-aid appliances, instruments and restoratives, an ambulance basket and stretcher.

The cost of these is about ... ... £11 10.

CONTRACTORS' PLANT.

Information relating to plant which is not mentioned in the present volume will be found in the under-named Sections of this series :—

SECTION I.

Portable engines and other motors, boilers, &c.

SECTION II.

Cranes, winches, winding and hauling plant, blocks and falls, chains, slings, wire and hemp rope, differential blocks and chains, hydraulic and screw jacks.

SECTION III.

Pumps and pumping machinery, contractors' pumps, tube well pumps, pipes, tubes and accessories.

SECTION IV.

Plant and stores for extensive works (pages 10 to 23).

Iron and wood working machinery and tools. Stocks, dies, and taps, vices, fitters' tools, carpenters' tools, saws, files, cramps, drills, glass and emery paper and cloth.

Bolts, nuts, and washers. Rubber and asbestos packings. Iron, steel and copper bars, plates, and sections. Soldering and brazing materials and tools.

SECTION VI.

Brick, tile and pipe making plant. Disintegrators. Appliances for water distillation.

SELECTION OF PLANT.—This is influenced by many conditions, such as magnitude of works and time allowed for their completion, local habits and resources, ultimate disposal of plant, and so forth.

A point also worth full consideration is, the extent to which mechanical appliances can be used in lieu or in aid, of animal and manual labour, which in some cases, is found to be quick enough, and (including the cost of skilled labour) cheaper than steam power.

In either case the approximate cost of suitable appliances can be obtained from the sources indicated above and from the following pages. A very complete schedule of plant and stores will be found at pages 10 to 23 of Section IV.

CAMP EQUIPMENTS.—It is scarcely within the scope of this volume to enter into details relating to equipments of huts or tents, furniture and utensils, stores of provisions, etc. for prospecting or surveying expeditions, advance working camps, etc. These are usually prepared under the supervision of the chief of the staff, but if information on these matters is required, it can be obtained if details are furnished as to the number to be provided for during a given time, nature of climate and country, facilities for transport and so forth.

MEDICAL STORES.—It seems singular that these (which cost only a few pounds) should ever be omitted when expeditions are unaccompanied by a medical man, and still more so is it that "first aid appliances" should not always be provided, one or more members of the staff having some training in their use.

WATER SUPPLY.—The importance of an ample supply of wholesome water for surveying, construction or mining camps, can scarcely be over-estimated, and it can usually be obtained by putting down tube wells. These are referred to at page 196.

An excellent example of this is found in an important exploration and surveying expedition (equipped by the writer) where scarcity of water was expected to present serious difficulties, and would have done so if the undernamed system had not been adopted.

The appliances for water supply consisted of two sets of apparatus for putting down tube wells, and for withdrawing them for use in another camp, the location of camps having been (approximately) determined. The mode of operation is described in Section III. of this series as follows:—

"**The tube well staff** were natives and the requisite number were sent in advance, with tube driving apparatus, to provide water supply for the next camp. The rest of the staff remained with the camp, and when it was broken up, the pumps, tubes, etc. were withdrawn for further use."

By means of this simple and inexpensive arrangement, the expedition always found an ample supply of water for themselves and their animals, on arrival at the new camp.

RAILWAY MATERIALS, LOCOMOTIVES AND ROLLING STOCK, see pages 89 to 107.

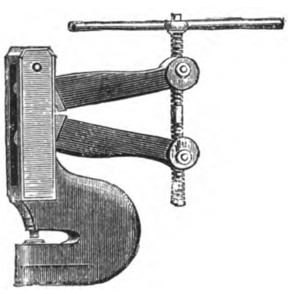


Fig. 5086.

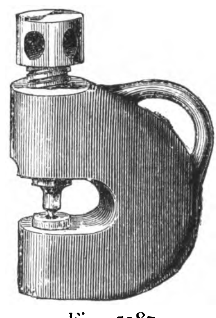


Fig. 5087.

DUPLEX SCREW PUNCHING BEAR.—The bodies of the tools Figs. 5086 and 5087, are made of forged steel, and each is fitted with a steel punch and die. The prices of spare punches and dies will be found below.

PRICES OF DUPLEX PUNCHING BEARS, FIG. 5086.

Diameter of hole punched ... inch	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	1
Thickness of plate punched ... ,,	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$
Depth of gap from centre of punch ,,	$1\frac{1}{8}$	$1\frac{1}{2}$	2	2	2	$2\frac{1}{4}$
Price of tool complete	£3 10	£4 10	£6	£6 10	£10 10	£15 15
Extra round punch and die, $\frac{1}{4}$ to $\frac{1}{2}$ inch ...	4/-	4/-	4/6	4/6	5/-	5/-
,, ,, ,, $\frac{9}{16}$ to 1 inch ...	...	5/-	6/-	6/-	6/6	7/-
Approximate weight ... ... lbs.	20	40	65	85	130	220

PRICES OF SCREW PUNCHING BEAR, FIG. 5087.

Diameter of hole punched	inch	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$
Thickness of plate punched	,,	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{5}{8}$	$\frac{3}{4}$
Depth of gap from centre of punch ...	,,	$1\frac{5}{8}$	$1\frac{15}{16}$	$2\frac{1}{8}$	$2\frac{1}{2}$
Price of tool complete	...	£2	£2 10	£3 15	£5
Price of tool with ratchet lever ...	...	£2 12	£3 2	£4 7	£5 12
Price of round punch and die, $\frac{1}{4}$ to $\frac{1}{2}$ inch	...	4/-	4/-	4/6	5/-
,, ,, ,, ,, $\frac{9}{16}$ to $\frac{7}{8}$ inch	...	...	5/-	6/-	6/6
Approximate weight	lbs.	23	38	56	85

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

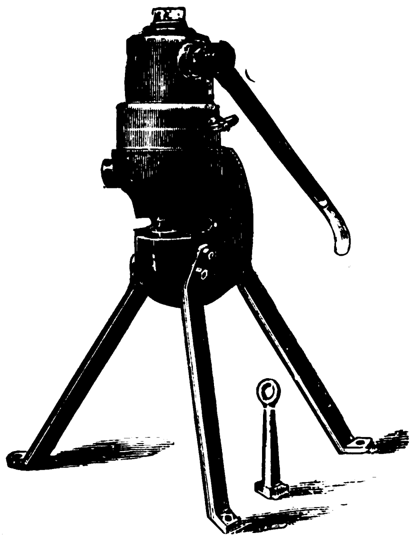


Fig. 5088.

HYDRAULIC PUNCHING BEAR.—Fig. 5088 represents an open mouth bear, as generally used for punching bars and ordinary sections.

The body, ram and plunger are of forged steel, the pump is in gun-metal, and the tool is complete with wrought iron support, wrought iron hand lever and pump wrench, and one punch and die.

Extra punches and dies can be obtained at the following tabulated prices.

PRICES OF HYDRAULIC PUNCHING BEARS, Fig. 5088.

Diameter of hole punched...	inch	$\frac{3}{4}$	$\frac{13}{16}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{1}{2}$
Thickness of metal ...	,,	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$
Depth of gap from centre of pump	,,	$1\frac{3}{4}$	$1\frac{3}{4}$	2	2	$2\frac{1}{4}$	$2\frac{1}{2}$
Price of tool complete ..	...	£7 10	£9	£10 10	£17 10	£21	£34
Extra round punch and die	inch	5/6	6/-	7/-	7/6	7/6	10/-
,, oval or square ,,	,,	11/-	12/-	14/-	15/-	15/-	20/-
Approximate weight ...	lbs.	71	90	125	200	340	480

CLOSE MOUTH HYDRAULIC PUNCHING BEARS.—The foregoing description applies to these, excepting that the mouth is adapted to punch rails, girders, etc.

The mouth of the tool is made to suit the section (or sections) to be punched, specimen or sketch with figured dimensions of which is required.

PRICES OF CLOSE MOUTH HYDRAULIC PUNCHING BEARS.

Diameter of hole punched ... . inch	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$
Thickness of section ... ... ,,	$\frac{1}{2}$	$\frac{3}{4}$	1	1
Price of tool complete	£12	£17	£28	£38
Extra round punch and die ... ... inch	5/6	7/-	7/6	10/-
,, oval or square ,, ... ,,	11/-	14/-	15/-	20/-

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

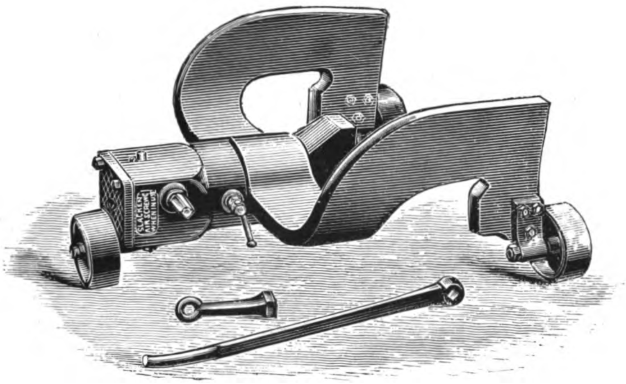


Fig. 5089.

HYDRAULIC TRAM RAIL BENDER.—The body of the machine represented by Fig. 5089 is of forged iron or steel and mounted on three wheels for facility in moving to its work, the pump ram is steel and the pump of hard gun-metal.

The frame is made to suit the rail, a specimen or drawing of which should be furnished.

PRICES OF HYDRAULIC TRAM RAIL BENDERS, FIG. 5089.

To bend steel tram rails weighing ... .. lbs. per yard	75	120
Span inside the frames ... ... inches	24	28
Price of machine	£27	£36

The cost of packing for shipment and delivery f.o.b. is 5 per cent.

RAIL BENDING MACHINE (Jim Crow).—The frames of both Hydraulic and Screw Machines, represented respectively by Figs. 5090 and 5091, are made of forged iron or steel rails of any section within the weights specified, specimen or dimensioned drawing should be supplied of the section to be bent.

PRICES OF HYDRAULIC RAIL BENDERS, FIG. 5090.

Weight of steel rail ... ... lbs. per yard	45	65	75	90
,, iron rail ... ... ,,	55	75	85	100
Span inside the frame ... ... inches	20	21	24	24
Price of machine	£6	£8 10	£9 10	£10
Approximate weight ... ... lbs.	105	165	200	220

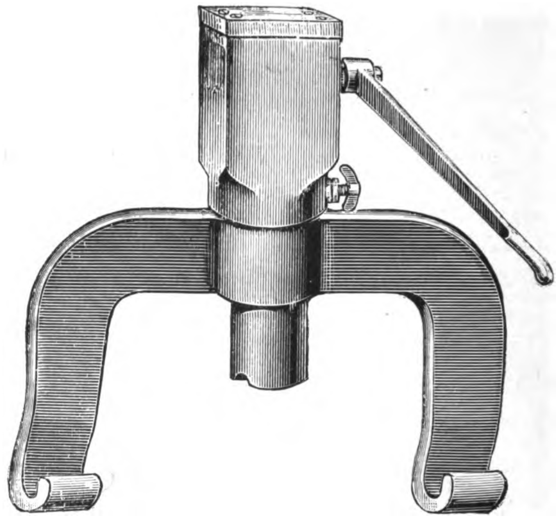


Fig. 5090.

SCREW RAIL BENDER (Jim Crow.)—The foregoing remarks on Hydraulic Benders apply equally to these :—

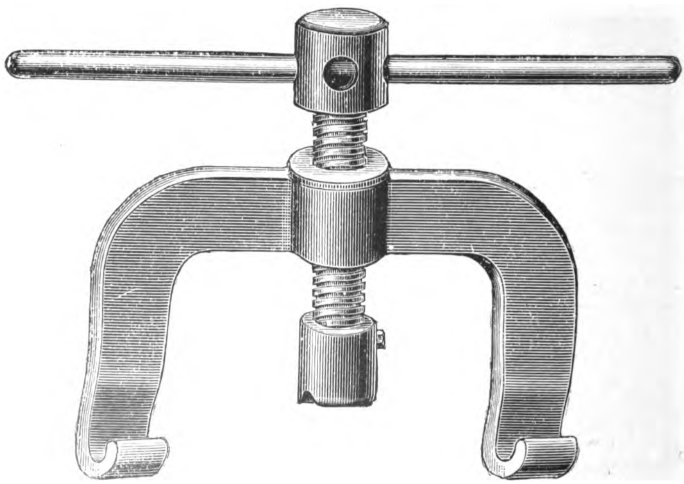


Fig. 5091.

PRICES OF SCREW RAIL BENDERS, FIG. 5091.

Weight of steel rail ...	lbs. per yard	16	20	45	65	75	90
,, iron rail ...	... ,,	24	30	55	75	85	100
Span inside the frame ...	... inches	14	16	20	24	24	24
Diameter of screw ...	... ,,	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$
Price of machine	... ...	£2 3	£2 10	£3 10	£5	£6	£7
Approximate weight ...	... lbs.	45	66	100	140	160	186

The cost of packing for shipment and delivery f.o.b. is 5 per cent.

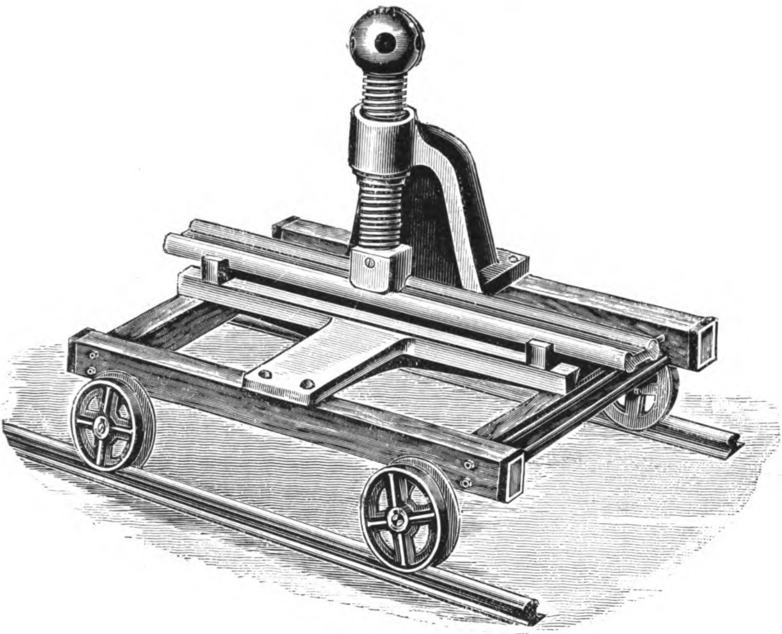


Fig. 5092.

PORTABLE RAIL STRAIGHTENER.—The trolley which carries the straightener is built of timber as shown in Fig. 5092, and mounted on four flanged travelling wheels to suit the gauge of track. A section of the rails to be straightened should be provided so that the sole plate may be made to fit it. The trolley can be built of rolled steel sections, the cost being somewhat increased.

PRICES OF PORTABLE RAIL STRAIGHTENERS, FIG. 5092.

Suitable for iron rails up to ... ... lbs. per yard	50	120
Price of straightener complete	£17	£25
,, ironwork only	£9	£17

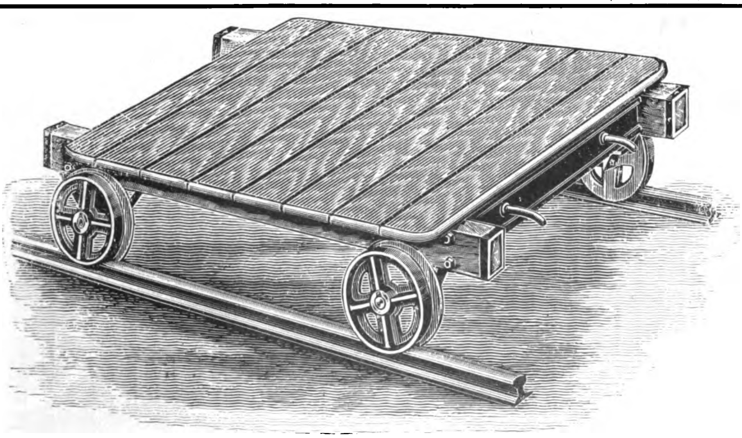


Fig. 5093.

PLATE-LAYERS TROLLEY, Fig. 5093.—The frame is of oak with the necessary bolts and bracings, wrought iron axles and four cast-iron flanged wheels for any gauge of track.

NARROW GAUGE TROLLEYS cost practically the same as those for 3-ft. $3\frac{3}{8}$-in. (metre) gauge.

PRICES OF PLATE-LAYERS TROLLEYS, FIG. 5093.

Gauge of rails ... ... feet	3 $3\frac{3}{8}$	4 $8\frac{1}{2}$
Price of trolley, heavy type	£6 1	£6 10
,, ,, light type	£4 15	£5 4
,, ironwork only, heavy type ...	£4 12	£6 3
,, ,, light type ...	£3 10	£4 18

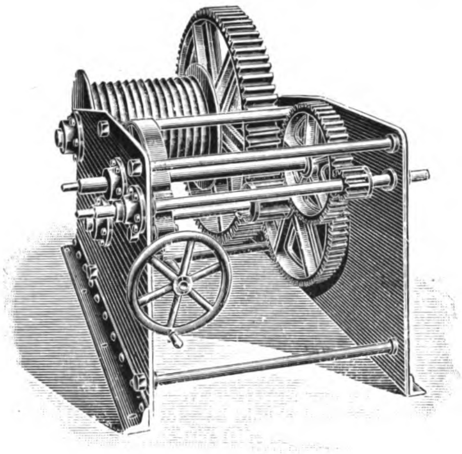


Fig. 5094.

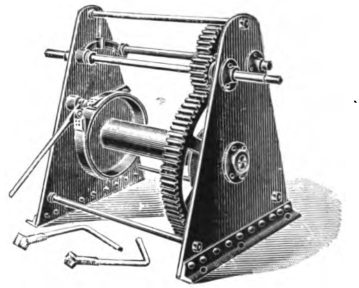


Fig. 5095.

HAND POWER CRABS.—The engraving Fig. 5094 represents a powerful treble purchase crab, and Fig. 5095 a double purchase crab of usual power. Both have wrought iron or steel plate side frames firmly connected by stay bolts, and fitted with screw or lever brake, as seen in the engravings.

They cost rather more than the ordinary crabs with cast iron sides, but are usually preferred in consequence of the absence of liability to breakage.

PRICES OF TREBLE PURCHASE CRABS, Fig. 5094.

Lifting power direct from barrel tons	3	4	5	6	8
,, with 2 and 3 sheave blocks ,,	15	20	25	30	40
Circumference of rope coiled inches	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5
Length of rope coiled ... feet	75	85	85	85	85
Approximate price of crab	£45	£50	£55	£60	£65

PRICES OF DOUBLE PURCHASE CRABS, Fig. 5095.

Lifting power direct from barrel cwts.	16	20	25	36	48	60	72
,, with 2 & 3 sheave blocks, tons	4	5	6	9	12	15	18
Length of barrel ... ... inches	16	18	19	21	22	26	26
Price of Crab with lever brake ...	£6	£6 10	£8	£9	£10 10	£12 10	£15 10
Extra for screw brake	26/-	28/-	28/-	30/-	35/-	50/-	55/-
Extra for gun-metal bushing ...	18/-	19/-	20/-	22/-	24/-	31/-	38/-

PRICES OF SINGLE PURCHASE CRABS, Fig. 5095.

Lifting power direct from barrel ... cwts.	8	12	16	20
Length of barrel ... ... inches.	12	15	16	18
Price of crab with lever brake	£4	£4 10	£5	£6
Extra for screw brake	6/-	7/-	8/-	10/-
Extra for gun-metal bushing	12/6	12/6	13/6	15/6

DOUBLE PURCHASE CRABS FOR ROPE are constructed as shown in Fig. 5095, but the barrels have the diameter requisite for coiling flexible steel wire or hemp rope without too great torsion, and with gear for lifting the load specified.

PRICES OF DOUBLE PURCHASE CRABS FOR ROPE.

Lifting power direct from barrel ... cwts.	8	12	18	24	30	40
Lifting power, 2 and 3 sheave blocks tons	2	3	4½	6	7½	10
Circumference of rope coiled ... inches	1¼	1½	1¾	2	2¼	2½
Length of rope ... ... feet	63	70	75	75	85	100
Price of crab with lever brake	£6	£8	£9	£10 10	£13	£20
Extra for screw brake	10/-	11/-	12/-	20/-	22/-	24/-
Extra for gun-metal bushing	18/-	20/-	22/-	24/-	32/-	40/-

HYDRAULIC AND SCREW JACKS.

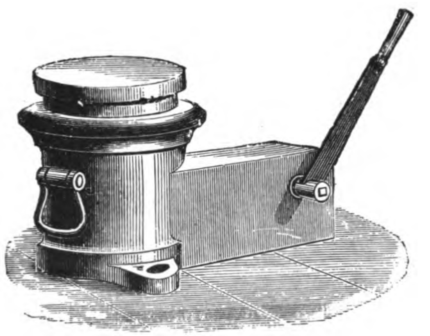


Fig. 5096.

HYDRAULIC SHIP JACKS are invaluable for lifting great weights. Fig. 5096 represents them as usually made, but they are capable of modification, only one example of which is illustrated here, but a special application of this system is illustrated and described at page 205.

HYDRAULIC SHIP JACKS, Fig. 5096.

Lifting power ... tons	12	20	35	50	70	100	150	200
Height when down inches	11	11	11	12	12	13	13	13
Stroke of ram ... ,,	6	6	6	6	6	6	6	6
Price of jack	£5	£5 15	£7 10	£9 5	£15	£19	£22 10	£26 10
Approximate weight lbs.	95	100	135	200	270	390	530	620

The test load is 25 per cent. more than the lifting power.

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

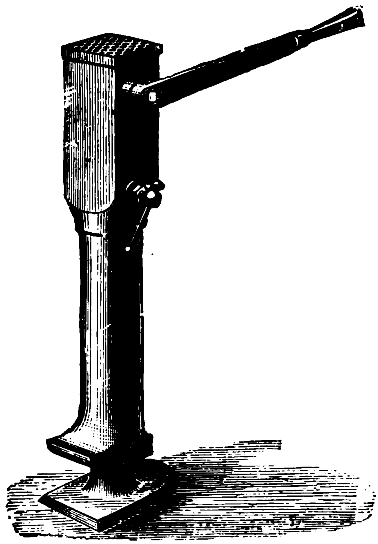


Fig. 5097.

Fig. 5098.

HYDRAULIC JACKS, Fig. 5097, are tested to 25 per cent. more than the load specified, and it can be lifted by the head or projecting foot of jack by one man.

PRICES OF HYDRAULIC LIFTING JACKS, Fig. 5097.

Lifting power tons	4	6	8	10	15	20	30	40	50	60
Height when down in.	23	24	26	27	28	28	29	29	29	29
Stroke of ram ,,	10	10	11	12	12	12	12	11	11	10
Price of jack ...	£3 15	£4	£4 10	£5	£6	£6 10	£7 10	£9	£10 10	£12 10
Approx. weight lbs.	52	68	72	88	105	130	165	220	260	335

HYDRAULIC TRAVERSING JACKS are as above described, and are provided with base, traversing screw and ratchet, as indicated in Fig. 5098.

PRICES OF HYDRAULIC LIFTING AND TRAVERSING JACKS.

Lifting power tons	4	6	8	10	15	20	30	40	50	60
Height when down ins.	26	27	29	30	31	31	32	32	33	33
Stroke of ram ,,	10	10	11	12	12	12	12	11	11	10
Traverse of jack ,,	6½	7	7	10	12	12	12	15	17	18
Price of jack ...	£5 15	£6 5	£7	£7 10	£9	£10	£13 10	£15 10	£20	£22 10
Approx. weight lbs.	95	105	112	130	165	215	310	345	490	565

TRAVERSING SCREW JACKS, Fig. 5098, are mounted on a malleable iron base and fitted with ratchets to both lifting and traversing screw.

PRICES OF TRAVERSING SCREW JACKS, Fig. 5098.

Lifting power ... ... tons	6	8	10	15	20
Height when down ... inches	20	20	21	22	23
Traverse of jack ... .. ,,	7	7	10	12	12
Price of jack	£3 3	£3 5	£4	£4 15	£7 10

TRIPOD SCREW JACKS, Fig. 5101, No. 32.—The legs and base are of wrought iron, and the neck is fitted with a gun-metal nut.

PRICES OF TRIPOD SCREW JACKS,

Lifting power ... ... tons	2	4	6	8	10	12	15
Height when down ... inches	10	15	20	22	22	22	23
Price of jack, Fig. 32	12/-	19/-	28/-	32/-	40/-	45/-	60/-
,, ,, with ratchet ...	16/-	23/-	33/-	38/-	46/-	53/-	68/-

WHEELS, AXLES, AND AXLE BOXES.—The following details relating to these materials will be useful when renewals are required, and for estimating the cost of such fittings for trucks built to carry.

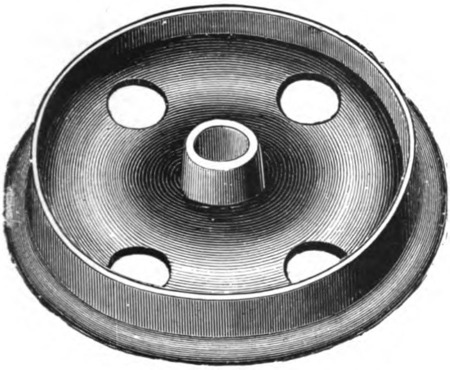


Fig. 5099.

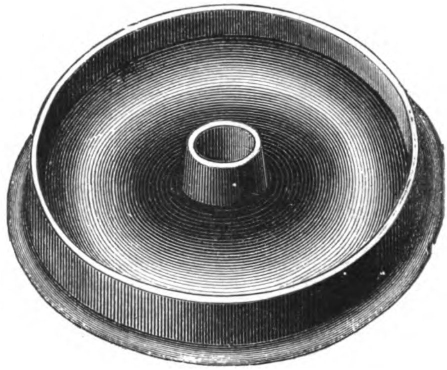


Fig. 5100.

CHILLED CAST IRON WHEELS are made of specially tough metal and chilled on the tread and flange, which makes these surfaces harder than steel and capable of resisting wear during long periods of constant service.

The following prices of a few of the sizes made include boring to fit the axle, facing, and key-seating.

PRICES OF CHILLED IRON WHEELS, Figs. 5099 and 5100.

Diameter of wheels ... inches	8	9	9	10	10	10	12
Load for four wheels ... tons	$\frac{3}{4}$	1	$1\frac{1}{4}$	1	$1\frac{1}{2}$	$2\frac{1}{2}$	1
Price for four wheels	8/-	9/6	11/6	10/6	12/6	16/-	14/-
Diameter of wheels ... inches	12	12	14	14	15	16	16
Load for four wheels ... tons	$1\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{2}$	4	$2\frac{1}{2}$	4
Price for four wheels	16/6	20/-	19/6	24/6	30/-	27/6	33/-
Diameter of wheels ... inches	18	18	21	21	24	24	24
Load for four wheels ... tons	3	5	4	6	5	6	8
Price for four wheels	£1 13	£2 1	£2 15	£3 15	£4	£5	£6

CHILLED CAST-IRON TRAM CAR WHEELS of the same metal and fitted and finished as last described.

Price per set of four wheels, 2-ft. diameter ... ... £3 17s. 6d.

,, ,, ,, ,, 2-ft. $5\frac{1}{2}$-in. diameter ... ... £4 5s. 6d.

AXLES AND AXLE BOXES.—The axles are of mild steel, turned to suit the bearings in the axle boxes and the bosses of the wheels.

The prices are for one pair of axles (two) and include keys to secure them in the wheels.

Axle boxes.—The prices are for a set of (four) boxes of the types in general use, ready for bolting to the underframes of rolling stock of any gauge.

PRICES OF AXLES FOR LIGHT ROLLING STOCK.

Load on two axles ... tons	½	1	2	2½	3	4	5
Price per pair up to 20-in. gauge ...	6/9	8/-	9/9	10/6	11/6	14/-	17/-
,, ,, 20-in. to 30-in. gauge	7/9	9/3	11/3	12/-	13/6	16/9	20/6

Load on two axles ... ... tons	2	2½	3	3½	4	5
Price per pair 30-in. to 3-ft. 6-in. gauge ...	12/9	13/9	15/6	16/9	19/9	23/6
,, ,, 3-ft. 6-in. to 4-ft. 8-in. gauge	...	16/3	19/-	20/6	24/3	28/6

PRICES OF AXLE BOXES FOR LIGHT ROLLING STOCK.

Load on two axles ... tons	½	1	2	2½	3	3½	4	5
Price for four plain bearings...	2/9	3/4	4/3	4/9	5/6	6/-	7/6	9/-
Price for four plain bearings, with grease boxes ...	5/9	7/-	7/3	7/9	9/9	10/6	11/6	13/6
Price for 4 bearings with grease boxes, brasses, springs & horns	22/3	29/6	34/6	37/6	42/6	45/-	51/-	57/9

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

"STROUDLEY" RAMPS for replacing derailed rolling stock are made in sets of four (two right and two left hand) and in the four sizes required for handling the under-named rolling stock.

For light railways, weight 14 lbs. each ... price £4 5s. per set.
For ordinary trucks, ,, 92 lbs. ,, .. ,, £8 0s. ,,
For heavy wagons, ,, 140 lbs. ,, ... ,, £13 15s. ,,
For locomotives, ,, 170 lbs. ,, ... ,, £19 10s. ,,

DOUBLE RAMPS serve the same purpose as those last named, but they can be used for either right or left hand.

The price per pair for ordinary wagons is £6 15s.; for locomotives, £11 5s.

The weight of each is respectively about 128 lbs. and 260 lbs.

CONTRACTORS' STORES AND TOOLS.

The quantity and kind of stores to be sent out will, naturally, be largely influenced by the character and extent of the work, and on the facilities for obtaining supplies locally.

It will very rarely be necessary to provide quantities so large or so varied as those mentioned at pages 17 to 24 of Section IV., but probably time and money will be saved if some, at least, of the under-named stores are sent out for commencement of operations.

Packing in the manner most suitable for the climate, means of transport and enconomical use of stores is a matter which by no means always receives the attention it deserves, inconvenience and loss being incurred by insufficient protection, sending out heavy casks or bags of materials which ought to be packed in small metallic kegs, or even sub-divided into smaller drums, and so forth. This involves some extra, but quite insignificant, expense compared with the ultimate saving.

Quantities.—No attempt is made to indicate the quantities of any of the stores to be provided, these evidently varying so widely that they can only be settled by the official in charge, or by reference to equipments which have been supplied for works of similar character and extent.

Sources of information.—Data relating to most of these stores and tools, which are not specifically dealt with in this volume, will be found in other volumes of this series as indicated at page 117.

The following list looks formidable, but the outlay involved is usually an unimportant item in the total cost of plant.

METALLIC STORES.—These consist principally of :—

- **Iron.**—Flat, round and square bars, some plate, sheet and hoop iron, and perhaps some L, T and H sections.
- **Cast steel.**—Octagon, square, round and flat bars.
- **Double shear steel** for steeling purposes.
- **Copper and brass** in sheets, bars, wire and gauze.
- **Lead** in sheet, wire, and perhaps some tubes.
- **Tin,** assorted sheets, block tin and materials for soldering.
- **Wrought iron tubes** and connections.

MISCELLANEOUS STORES.—These will probably comprise :—

- **Bolts, nuts,** bolt ends and washers of useful sizes.
- **Nails, wood screws** and coach screws.
- **Rivets,** iron and copper, and rivetting tools.
- **Steel and iron wire,** copper, brass and lead wire.
- **White and red lead,** boiled oil, linseed oil.
- **Paints,** turpentine, dryers, brushes and cans.
- **Asbestos and rubber** sheets, rings, or other packings.
- **Lubricating oils,** grease, waste, spun yarn.
- **Kerosine,** large and small lamps, wicks, etc.
- **Oil cooking stoves** and utensils.
- **Hand power crabs** or winches.
- **Screw or hydraulic** jacks.
- **Best tested chain,** blocks, hooks, slings, etc.
- **Differential blocks** (self-sustaining).
- **Ropes** and rope blocks.
- **Galvanized corrugated iron,** bolts, etc.
- **Roofing felt** and pitch.
- **Portland cement, bitumen, etc.**
- **Contractor's pumps** and accessories.
- **Tube well pumps** and tube driving gear.
- **Emery and glass cloth,** emery powder.
- **Locks, bolts,** hinges, hasps, latches and similar fittings.
- **Drawing and other instruments,** and replace parts.
- **Soldering tools** and materials.
- **Sheet glass, glazier's diamond,** glazier's tools and materials.

TOOLS.—In addition to those mentioned in the preceding and following pages, for the most part with prices, a supply of files and small hand tools, hand saws, frame and cross cut saws and, probably some carpenter's tools will be required, also tools for pipe screwing and laying.

Machine tools.—The last remark may often be made with reference to a small equipment of lathes, punching and shearing, drilling, and even a shaping machine for the smith's shop, a circular saw bench, or general joiner, a boring and mortising machine, etc. is often found invaluable in the carpenter's shop.

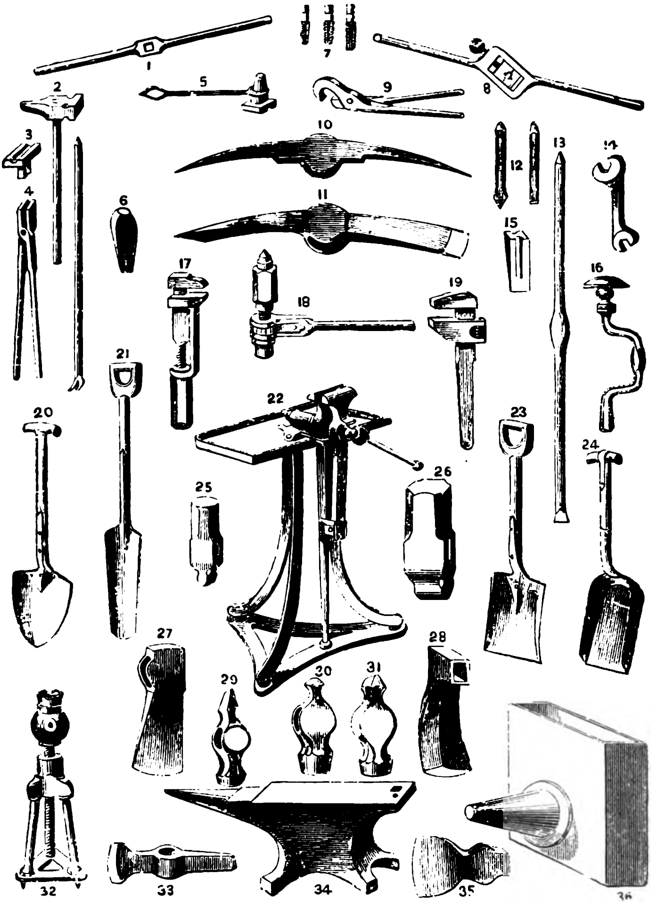


Fig. 5101.

Different countries employ different tools, but those now referred to by their respective numbers and generally indicated in the engraving Fig. 5101, are such as are used in the best practice of English speaking nations.

BLACKSMITHS' TOOLS.—A set which often suffices for ordinary repairs to Contractors' plant comprises :—

A steel-faced anvil weighing about $3\frac{1}{2}$ cwt.
8 each top and bottom swages (16 in all), sizes $\frac{1}{2}$ $\frac{5}{8}$ $\frac{3}{4}$ $\frac{7}{8}$ 1 $1\frac{1}{4}$ $1\frac{3}{4}$ $2\frac{1}{4}$ inch.
1 bottom or anvil fuller, 1 top fuller, 1 flatter.
2 snap tools (hand and rod), 2 hot sets for rod and anvil, 1 steel cold set.
1 square faced set hammer, steel rod punches (3 sizes).
Nut mandrils (4 sizes), 2 hand punches.
Round rod punches (3 sizes), square rod punches (3 sizes).
2 bolt forging tools (four sizes), 1 sledge hammer (14-lbs.), 1 flogging hammer (7-lb.)
4 pairs round-mouthed and 4 pairs open-mouthed tongs, different sizes.
4 pairs close-mouthed tongs, different sizes, and pair smiths' pliers.
2 pairs bolt tongs, different sizes.
Set of smiths' firing tools.

The cost of the above-named tools is about £22

ANVILS, steel faced (Fig. 5101, No. 34), for ordinary smiths' work, usually weigh 3 to 4 cwt. (say 3½ cwt.) and cost about 33/- per cwt.

CAST-IRON SWAGE BLOCKS cost about 14/- per cwt. A generally useful size weighs about 6 cwt.

CAST-IRON STANDS for anvils and swage blocks weigh about 1½ to 2 cwt. and cost about 15/6 per cwt.

TUE IRON WITH CISTERN (Fig 5101, No. 36)

Length ... ... inches	21	23	26
Price each	34/-	41/-	53/-

PORTABLE FORGES strongly built of wrought iron, hearth with trough, about 30 inches long by 25 inches wide, circular double blast bellows, weights and all fittings, price £9

PORTABLE VICE BENCHES (Fig. 5101, No. 22), with wrought iron stand and solid box vice.

PRICES OF PORTABLE VICE BENCHES.

Width of jaws .. .. inches	4	5	5½	6
Price as illustrated	£2 10	£3 7	£3 15	£4 0
,, mounted on wheels	£2 15	£3 12	£4	£4 12
,, ,, ,, with tool box ...	£3 5	£4 2	£4 15	£5 17

SMITH'S FORGES, BLOWERS, FANS, BELLOWS, etc. (see Section IV. pages 159 to 164.

GRINDSTONE AND FRAME.—The grindstone spindle is fitted with handle and pulley, and is carried in bearings fixed on an iron frame which forms a trough.

They are made in all sizes from 18-in. by 3-in. (size of stone) to about 48-in. by 10-in.; the sizes above 30-in. diameter are usually fitted with pulley for driving by belt.

PRICES OF GRINDSTONES AND TROUGHS.

Diameter of stone ... ... inches	18	18	24	26	30
Thickness ,, ... ,,	3	4	4	4	5
Price of stone with frame and accessories	£2 10	£2 15	£3 15	£4 5	£5 12

PRICES OF TOOLS (FIG. 5101).

BLACKSMITHS' TOOLS (No. 1 to 6), price about 1/- per lb.

ENGINEERS' OCTAGON STEEL CHISELS (No. 12), usual sizes ¾-in., ⅞-in. and 1-in., 7 to 10 inches long with straight, half-round, diamond or round points, price 10d. per lb.

DOUBLE END SPANNERS (No. 14), are made in all sizes, from 6-in. long with ends ½-in. and $\frac{5}{16}$-in., to 22-in. long with ends 1⅝-in. and 2-in., the under-named being generally useful sizes. The wrought-iron spanners with case-hardened bright faces are the most satisfactory, but the stamped steel spanners may answer every purpose for occasional or light work.

Length ... ... inches	10	13½	18	20
Sizes of ends ... ... ,,	½ × ⅝	¾ × ⅞	1 × 1⅛	1¼ × 1⅜
Wrought iron, case hardened faces price each	2/10	3/9	5/-	7/-
Stamped steel ... ... per dozen	13/6	26/6	40/-	47/6

SCREW WRENCHES (No. 17), are made with single or double bar, and 6-in. to 16-in. long.

Length ... ... inches	7	8	10	12	14
Single bar (No. 17)... price each	2/8	2/10	3/3	4/6	5/3
Double bar wrench ... ... ,,	5/6	5/9	6/6	7/6	10/-

ADJUSTABLE (BUDDING) SPANNER (No. 19).

Length ... ... inches	6	8	10	12	14
Range of span ... ... ,,	1	1¼	1½	1¾	2
Price each...	5/-	5/6	7/3	8/6	9/9

CLYBURN ADJUSTABLE SPANNERS are made from 6 to 24 inches long, the spans ranging from ⅝ in. to 2¼ in.

Length ... ... inches	6	8	10	12	15
Range of span ... ... ,,	⅝	¾	1	1¼	1½
Price of spanner	4/3	5/3	6/6	8/-	9/9

FITTER'S BRIGHT WROUGHT IRON BRACE (No. 16), price 6/6 each.

SLEDGE HAMMERS (Nos. 25 and 26), price 6d. per lb.

Ash handles cost 3/9 to 6/6 per dozen.

Hickory handles cost 5/6 to 7/6 per dozen.

RIVETTER'S STEEL HAMMERS, snaps, etc. cost 10d. to 1/- per lb.

ENGINEER'S STEEL HAMMERS (Nos. 29, 30 and 31.)

Weight each ... lbs.	½	¾	1	1¼	1½	2
Price per dozen	12/-	13/6	15/-	17/-	20/-	25/-

The price of hammers 2¼ to 4 lbs. weight is 10d. to 1/- per lb.

Ash handles cost 2/6 to 4/6 per dozen.

Hickory handles cost 3/- to 5/6 per dozen.

RATCHET BRACES (No. 18).

Length ... ... inches	12	14	16	18	20	22
To drill up to ... ,,	¾	1	1¼	1⅜	1½	1¾
Price of brace (No. 19) ...	12/-	14/-	16/-	18/-	20/-	22/-
,, differential brace ...	16/6	18/-	19/6	21/6	23/-	26/6

CAST STEEL DRILLS (No. 12) for ratchet braces or drilling machines.

Drills up to ... ... inches	1	1⅛ to 1½	1¾ to 2
Price per dozen ... ... about	12/-	18/-	22/-

DRILLING AND BORING MACHINES see Section IV. pages 43 to 58.

SCREW STOCKS AND DIES. Various types of these tools are illustrated and described in Section IV. of this series, and the undernamed are abstracted as being usually sufficient for preliminary or temporary repair shops.

The prices include the stocks, with dies and taps for bolts and nuts of the sizes mentioned; the advantage of having Master taps is, that worn or broken taps can be replaced, on the spot, by any good blacksmith.

To screw and tap					with taper and plug tap	with taper, 2nd plug and master tap
$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	inch ...	£1 10	£2 5
$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	,,	£2 0	£3 3
$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	,,	£2 13	£4 6
$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	,,	£3 16	£6 5
$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	,,	£5 13	£9 6
$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	,,	£10 10	£17 6

A SET OF SCREW STOCKS, &c. IN CASE containing two sets of stocks with dies and plug and taper taps for bolts and nuts $\frac{1}{4}$ to $\frac{1}{2}$-inch diameter costs £16.

If with taper, 2nd, Plug and Master tap, the price is £23.

GAS TUBE DIES AND GUIDES to fit the above-named Stocks, and to screw $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$-inch gas or steam tube, can be supplied for about £3 4s.

KENT FELLING AXE (Fig. 5101, No. 27), are made in weights from $1\frac{1}{2}$ to 7 lbs. each. The price is 1/1 per lb. and the usual weights are from $3\frac{1}{2}$ to 6 lbs.

KENT POLE AXE (No. 35). The price is 11d. per lb. and the weights are about the same as felling axes.

AMERICAN FELLING AXES.—The price is $\frac{1}{2}$d. per lb. and the weights range from $3\frac{1}{2}$ to 7 lbs.

CARPENTERS' ADZES (No. 28).

No. ...	1	2	3	4
The price each is ...	3/-	3/3	3/6	3/9

AXE HANDLES.

Length ... ... inches	18	21	24	30	36
Best ash, straight ... per dozen	3/3	3/9	4/6	5/6	8/-
Best ash, bent ... ,,	3/8	4/3	5/3	6/6	8/9
Hickory, American pattern, 36 inches long, 9/6 per dozen.					
Carpenters' Adze handles, Ash, 30 inches long, 7/6 per dozen.					

MORTISING AND BORING MACHINE.—A machine worked by hand-power and capable of cutting a mortise to any depth up to 6 inches, and to take in timber up to 8 inches wide, often saves much time and labour in wood-working.

The price of the machine with 8 mortising chisels $\frac{1}{4}$ inch to 1 inch, a core driver, boring apparatus with 3 steel drills for iron and 3 augers for wood, is ... £14 10s.

If without boring apparatus, drills and augers, the price is ... £13 5s.

WOOD-WORKING MACHINERY, SAW BENCHES, &c. see Section IV. pages 99 to 119.

GRAVEL OR NAVVY SHOVELS (Fig. 5101, No. 20).

Size No. ...	2	3	4	5	6
Price per dozen ...	24/-	24/9	25/6	26/3	27/-

GRAFTING TOOLS (No. 21).

Length of blade .. .. inches	12	13	14
Price per dozen	25/6	26/6	30/-

SQUARE (LONDON) SHOVELS (No. 23) range in size from 8¼ × 10½ to 12½ × 15 inches, the following being useful sizes.

Size No.	1	2	3	4	5	6
Price per dozen	21/6	22/3	23/-	24/-	24/9	25/6

STOKERS' STEEL SHOVELS (No. 24) range in size from 12 × 9¼ inches to 17 × 9¾ inches, and cost 40/- to 42/- per dozen.

SPADES (LONDON) WITH TREADS.

Size No.	1	2	3	4
Price per dozen	21/6	22/3	23/-	24/-

With long strap and rivetted eye 4/6 per dozen extra.

PICKAXES, SOLID EYE AND STEELED (Fig 5101. No. 10). Price 29/- per cwt.; usual weights about 6 7 8 and 9 lbs. each.

MATTOCKS, SOLID EYE AND STEELED (No. 11). Price 32/- per cwt.; usual weights about 6 7 8 and 9 lbs. each.

PICK AND MATTOCK HANDLES.

Length ... ... inches	36	39	42
Hickory ... ... per dozen	6/9	8/4	9/-
Ash ... . ,,	7/6	9/6	11/-

PLATELAYERS' (OR BEATER) PICKS, solid eye and steeled. Price 34/- per cwt.; usual weights about 8 9 10 to 12 lbs. each.

PLATE-LAYERS' KEYING HAMMER.—Price 7d. per lb.

PLATE-LAYERS' ASH LEVER, with steel straps and shoe at the lower end. Levers more than 8 feet long have a ring and handle near to the end of the strengthening straps.

Length of lever .. feet	6	7	8	10	12½	15
Price of lever	13/9	16/9	£1 0 6	£1 9	£1 15	£2 3

PLATE-LAYERS' RAIL LIFTING SCREW JACKS range in price from 25/- to 45/- each. The height when down is about 25 inches, and a generally useful size costs 40/-

SCREW RAIL LIFTER.—Two of these should be supplied for each gang of plate-layers, so that one man can place the lifter, and raise the rail, whilst the other men are packing sleepers and preparing another portion for lifting.

The price of lifters for light rails is ... . £2 10s. each.

,, ,, for heavy rails is ... ... £3 ,,

PLATE-LAYERS' AND INSPECTION RAIL GAUGES of wrought iron in sets of 5 pieces, give every dimensions and are made for lines of any gauge.

The price of a set for 4-ft. 8½-in. in gauge is ... ... £2 15s.

PLATE-LAYERS' SPANNERS.—The price of spanner for ¾-in. bolts is 3/- and 3/6 or 1-in. bolts.

PLATE-LAYERS TOOLS.—The subjoined specification comprises the standard outfit for a Colonial main line of 4-feet 8½-inches gauge, where repairs must frequently be made at considerable distances from important stations.

The approximate price of each item is given to facilitate the preparation of estimates for outfits differing from this in the quantity of tools required.

The prices left blank will be found under the respective headings relating to those articles.

Specification of plate-layers tools :—

	each.	£	s.	d.
6 Beaters with pick at one end, handled	2/10	0	17	0
6 Gravel shovels	2/9	0	16	6
2 Levers for lifting the rail on the road	15/-	1	10	0
6 Iron crow bars with steeled ends (about 12-lbs. each)...	2/7	0	15	6
1 straight-edge and sight	—	0	18	0
1 Spirit level on straight edge	—	1	5	0
18 Cold chisel	2/6	2	5	0
18 ,, ,, with safe rods	3/-	2	14	0
1 Ratchet brace, 18-inches, for holes up to 1-inch. diam.	—	1	7	0
36 Steel bits for holes up to 1-inch. diameter	1/3	2	5	0
1 Cramp 18 inches for ratchet brace...	—	1	10	0
6 Bright screw augers, ½-inch. with handles	2/-	0	12	0
3 ,, ,, ¾-inch. ,, ...	2/8	0	8	0
6 Spanners for fish bolts	3/5	1	0	6
6 Box spanners for fang bolts	8/6	2	10	0
4 Flags (2 red, 1 white, 1 green)	1/3	0	5	0
3 Sleeper adzes, handled	5 3	0	15	9
3 Sledge hammers with handles (about 10-lbs. each) ...	5/3	0	15	9
3 Hand hammers with handles (1½ to 2-lbs. each) ...	1/5	0	4	3
2 Mauls	8 -	0	16	0
1 Tricolour hand-lamp	—	0	13	0
2 pairs of lifting clips	18/6	1	17	0
2 Iron hooks for turning over	3/6	0	7	0
1 Template for adzing	—	0	10	0
		£25	17	3

4 Plate-layers trolleys (see page 122) ... ...
2 patent rail benders or rail presses (see page 122) ...
1 Jim-crow and bar (see page 121)

PORTABLE RAIL DRESSING PLANT.—Appliances for this purpose comprise machines for sawing off the worn ends of rails and for drilling fresh fish bolt holes, rail straightener, etc.

These machines are carried on a strong truck with engine and boiler, and it is stated that 400 to 500 rails can be dressed per day at a cost of about 3/- per ton, with considerable saving in the cost of carriage and handling.

RAIL-END DRILLS are made complete with ratchet brace and bridle to clip the drill to the head or foot of the rail, and the price of the apparatus with adjustable self-acting, or hand feed and two flats, or one twist drill, is £2

CONTRACTORS' END AND SIDE TIP WAGONS of the usual kind are built of timber, strengthened by wrought-iron bands, and fitted with wrought-iron axles, cast-iron wheels and bearings.

PRICES OF TIP WAGONS.

Capacity of wagon ... ... cubic yards	1	1¼	1½
Price of end tip wagon	£7 5	£7 17	£8 10
,, side tip wagon	£7 12	£8	£8 12

DOBBIN CARTS usually cost £11 to £12 each.

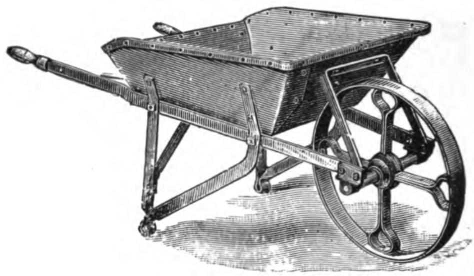


Fig. 5098A.

WROUGHT-IRON NAVVY BARROWS.—The frame and body are of wrought-iron and can be shipped in separate pieces with bolts or rivets for putting them together at destination to save cost and damage in transport. The wheel is wrought iron, 18 inches diameter, with tyre two inches wide, central cast-iron boss, and wrought-iron axle.

The price of wrought iron barrows, varnished, is 25/-

If with galvanized iron bodies, the price is 29/-

A lighter type costs about 3/- less, but is not so durable as those referred to.

BARROW WHEELS AND AXLES, as above described, cost 5/6 each.

Light pattern, with tyre 16-in. by 1½-in. costs 4/6

WOOD NAVVY BARROWS.—The body usually measures 30 by 20 inches at the top and 17 by 15 inches at bottom ; the sides are 9 inches deep and the front board 10 inches deep. The wheel is hooped and 18 inches diameter and the body strengthened by through bolts.

The price of these barrows is about 13/- each, and they can be shipped in pieces which are easily put together.

STEEL RETAINING STRUT.—This simple contrivance (not illustrated) saves time in putting in struts to prevent collapse in trenches being excavated, and—what is frequently more important—saves much time in applying the strut.

It consists of a steel tube fitted with a screw at one end, which can be regulated to any length between 27 inches and 42 inches, to suit the width of trench. The other end is pivotted, and is self-adjusting to any irregularities in the sides of the trench, and both ends are provided with claw feet which take a bearing on planking, or rock as the case may be.

MATERIALS FOR FENCING.—The varieties of continuous bar and hurdle fencing are too great for illustration and description in this section, but the following information relating to wire fencing may be useful for preliminary estimates, prices must, however, fluctuate in proportion with cost of raw materials.

FENCING WIRE is sent out ready for fixing to timber standards, or complete with iron standards and all accessories for forming a strong and durable fence.

The prices are for wire only, delivery on railway wagons at makers works.

FOUR BARBED STEEL WIRE is made in 2 ply and 3 ply, the barbs being usually about 6 inches apart and it is coiled on reels carrying ½ cwt. and 1 cwt.

The price of 2 ply barbed wire on 1 cwt. reel (about 560 yards) is about 18/3.

The price of 1 cwt. of 3 ply barbed wire (about 400 yards) is about 18/9.

ROUND STEEL FENCING WIRE.—The following list gives the approximate number of feet in each 1 cwt. of wire.

The price per cwt. of the wire, annealed and oiled is about 15/6.

,, ,, ,, galvanized, 17/-

FEET IN 1 CWT. OF FENCING MATERIALS.

Gauge ... ... No.	2	3	4	5	6	7	8	9
Number of feet in 1 cwt. ...	570	684	807	966	1179	1401	1698	2100
Breaking strain ... lbs.	4848	4622	4240	3750	3332	2912	2492	2044

SEVEN-PLY GALVANIZED WIRE STRAND FOR FENCING.

Size ... ... No.	1	2	3	4	5	6	7	8
Feet in 1 cwt.	600	678	780	921	1176	1395	1638	2097
Price per cwt.	21/-	21/3	21/6	22/-	22/6	23/3	24/-	24/6

PAINT SPRAYING MACHINES.—The advantages claimed for painting by pneumatic pressure are low cost and great rapidity with which the work is performed—one man being able to cover as large a surface as ten ordinary painters can do in the same time—and the facility it affords for reaching crevices and corners which are quite inaccessible by brush painting.

The apparatus consists of a cylindrical vessel for a supply of paint, with fittings to connect the vessel with an air compressor which supplies the pneumatic pressure, and a nozzle through which the paint is projected on the surface to be covered.

The price of the apparatus is about £4

PAINT SPRAYING MACHINE WITH COMPRESSOR.—The compressor is worked by hand-power, and the apparatus is complete with pressure gauge, nozzle, and connections for the paint and compressed air tubes.

The price of the apparatus is about £16

PLANT FOR TRACK BALLASTING AND LEVELLING.—The ballast is carried in trucks specially built to deposit it centrally or on either side of the track, as required for formation or re-ballasting railway tracks.

If the ballast is deposited centrally, the rear truck is fitted with appliances adjustable for spreading or levelling, and although this mode of working may not be considered desirable for the high-class roads and high speeds demanded in this country, it seems to be quite satisfactory where rapid progress and low cost of construction are the chief considerations.

The plant usually consists of a steam navvy (Fig. 5105), or a curved scoop, which load drop-bottom or side-opening trucks adapted for discharging the whole or any portion of the load at any point desired. The quantity delivered over a given area is regulated partly by the degree of opening provided, and partly by the speed at which the trucks are hauled.

A similar result is obtained by using flat bottom trucks with a plough scraper, the action of which resembles the "steam shovel" used in discharging grain from box cars into the elevator well.

Ballast spreader.—The end truck is fitted with adjustable wings which distribute the ballast in the direction and to the extent desired.

For re-ballasting existing roads, a pair of scrapers are fixed at the proper level which clear the rails to the flanges, and the sleepers are then ready for packing in the usual manner.

Hydraulicing ballast.—In exceptional cases, a water jet similar to that used in hydraulic mining has been employed for carrying the ballast in troughs or "flumes," which are moved to discharge where desired. In some instances the jet has been used for "getting" as well as carrying the ballast.

The cost is said to average about 3d. per cubic yard.

DRAG SCRAPERS made of seamless steel, with face hardened and rounded, and fitted with guide handle and drag bridle for grading in ordinary soil, sand, etc.

The price of scrapers 7 feet capacity is £2

The weight is about 90 lbs.

Scrapers of 5 feet capacity cost, each £1 16

Steel bottom plate, extra for either size 5/-

ROAD ROLLERS AND TRACTION ENGINES.

STEAM ROAD ROLLERS.—The great durability of roads consolidated by steam rollers is due to the materials being compressed and interlocked to form a pavement much more compact and level than can ever be attained if roads, newly laid or mended, are used for traffic without such consolidation.

Formation of road bed.—New metal, evenly laid after the road bed has been scarified, is consolidated by rolling the gravel, stone, screenings or other materials, together with an ample supply of water distributed in front of the roller as it advances ; this produces a compact and very durable surface.

Cost of road rolling.—A 15 tons steam roller will properly consolidate 2,000 superficial yards of carriage way in 10 hours at a cost, including all working expenses, repairs, interest on capital, etc. of about one-fifth of a penny per yard of roadway.

Weight of roller.—This ranges from 4 to 30 tons, but if the roller is too heavy the materials may be crushed rather than consolidated, whilst if too light more journeys must be made and the road is proportionately less durable. The work performed by machines weighing 10 to 15 tons is usually quite satisfactory for all roads.

Construction.—All machines, whether with single cylinder or compound engines, have two speeds of gear for travelling, and steering gear which will turn the roller round in about its own length. All operations are controlled from the driver's platform, and the work performed is equally good on a level road or on steep gradients, up to—say—1 in 7.

Compound engines are as easily worked as single cylinder engines and the advantages they afford are economy in consumption of fuel and more silent working.

PRICES OF STEAM ROAD ROLLERS.

Weight of roller ... ... tons	10	12½	15
Price of single cylinder engine	£395	£410	£500
,, compound engines	£450	£465	£578

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

STEAM ROLLER WITH SCARIFIER.—The scarifier which picks up the old road and prepares it for repair with new materials, consists of a simple arrangement of picks carried in a steel frame attached to the rear end of the machine, and is invaluable where roads must be quickly re-instated.

The picks are adjustable to inequalities of surface and are worked by power transmitted from the engine in travelling in either direction.

Work performed.—A 10 tons steam road roller with scarifier will break up 4,000 to 5,000 square yards of road per day.

Cost of scarifier.—Any of the last named engines can be provided with scarifier and gear to work it at an extra cost of about £100

STEAM ROLLER AND STONE BREAKER.—In road making, as in many other operations, a considerable saving in time and cost may be effected by preparing the materials more or less in situ.

A portable stone breaker of the type Fig. 5132, with screen as indicated in Fig. 5133, is available for use in the depôt, or on the highway itself, the stone breaker and screen being driven by power transmitted from the roller engine.

WATER BALLAST ROAD ROLLER.—A heavy cast-iron water-tight cylinder is filled with water to increase the effective weight when required, and the carriage is made with or without a turntable frame.

Turntable frame.—The object of this is to admit of turning in limited space, or of varying the direction of traverse without injury to the road or turf, or strain on the horses.

The extra cost of this useful adjunct is about £10 and it adds 7 to 15 cwt. to the weight of the roller.

PRICES OF WATER BALLAST ROAD ROLLERS.

Length of roller... ... feet	4	4½	4½	4½	4½	4½	5
Diameter of cylinder ... ,,	3½	3½	4	4½	5	5½	5½
Weight when empty ... tons	2½	3	3½	4	4½	5	5½
,, ,, filled ... ,,	3½	4	4¾	5½	6	7	8
Price of roller	£60	£70	£80	£90	£100	£115	£135

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

TRACTION ENGINES, which must often haul loads over trackless and uneven ground and under circumstances where it would be almost impossible to employ animal traction, must be subject to exceptionally rough usage, but with the high quality of materials and workmanship now obtainable the cost of maintenance is remarkably low.

TRACTION ENGINES FOR LONG DISTANCE HAULAGE, now referred to, are mounted on springs and fitted with winding drum and 75 yards steel wire rope for use when (for various reasons) the adhesion of driving wheels is insufficient, or for hauling.

Hauling power and speeds.—An engine of nominal horse power is capable of hauling 25 to 30 tons over a fairly good level road, or about 20 tons over a gradient of 1 in 15, at a speed of 4 miles an hour.

A slow speed (about 2 miles an hour) is provided, but is used only when travelling over exceptional gradients, or very rough roads.

Compound engines.—The large economy in the consumption of fuel and water (about 30 per cent) and the comparative noiselessness of compound engines are, sometimes, very important features.

TRACTION ENGINES FOR LONG DISTANCE HAULAGE.

Nominal horse power	8	10
Width over travelling axles ... ... feet	7¼	7½
Price of single cylinder engines	£620	£700
Price of compound engine	£700	£800
Canopy over driver's platform	£12	£15
Weight with fuel and water (working order) ... ... tons	13¼	15½

AGRICULTURAL TRACTION ENGINES, for hauling comparatively short distances and for driving other machinery, are fully equipped for these purposes and are fitted with winding drum and 50 yards of steel wire rope and hauling gear, but these engines are not usually mounted on springs, and they are not included in the following prices.

The speeds of travelling are 1½ and 3 miles per hour.

PRICES OF AGRICULTURAL TRACTION ENGINES.

Nominal horse power	6	7	8	10
Price of single cylinder engine	£460	£485	£520	£595
Price of compound engine			£600	£695
Extra if with enlarged fire box	£10	£12	£12	£15
Weight with fuel and water (working order) tons	8¾	10	11¾	13

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

TRACTION WAGONS.—High side trucks, timber trollies, box trucks and other types are built with or without springs, but wagons with wrought iron wheels and spring draw-bar can be obtained at about the undernamed prices.

Carrying capacity ... ... tons	4	6	8
Price of wagon	£65	£75	£85
,, ,, with springs	£75	£85	£97

MORTAR GRINDING AND MIXING MACHINES

Many combinations of edge-runner mills are made for grinding and mixing mortar, cement, minerals, slag, refuse and many other substances, wet or dry, but all are based on one of the two under-named principles of construction.

In the generally approved type represented by Fig. 5102, the revolution of the pan causes the runners to rotate, whilst that illustrated by Fig. 5104, also largely used, has a stationary pan, the runners, which are free on the cross arms, being rotated by the revolution of the central spindle.

False bottoms.—The pans for both types have loose bottom plates in segments which are easily removed when worn. The last-named (Fig. 5104) can be made with perforated or grid bottoms for grinding dry materials and discharging them automatically when pulverised to the required fineness.

The edge runners have flush sides which throw the materials back under the runners, and hoops can be obtained for quickly renewing the crushing surface and weight when worn.

Adjustable scrapers are provided to collect the materials from the sides of each runner and deliver them under it.

Concrete mixer blades can be fitted to any of the pans, so that the mill may be used for grinding mortar or mixing concrete. The blades are easily fixed and the cost of them will be found at page 140.

The driving shaft is fitted with a pulley of the dimensions given in the following table and is long enough to take a loose pulley, if it is required, the cost will be found below. The bearings for the shaft, and those for the ante-friction rollers under the pan, are secured to the bed plate. These rollers are not required for pans of less than 7-ft. diameter.

Bearings.—Provision is made for the bearings of the driving shaft, and of the mill spindle, being easily renewed when worn.

Mill spindles.—Wrought iron is preferable to the cast iron shaft with which mills are usually fitted and should be adopted for heavy or continuous work. The extra cost is given at page 140.

The bed plate is adapted for fixing to a masonry or concrete foundation, or to a timber or iron frame, and is designed to give the rigidity required for working with minimum wear and tear.

Proportions of parts.—The following information affords data for estimating the size of the mill required for a given range of work, and the motive power to be provided.

Output per hour.—This necessarily varies according to the materials and the extent of grinding and mixing required, but the figures in the table may be used as representing mean results.

PROPORTIONS OF REVOLVING PAN MILLS.

Diameter of pan ... feet	4	5	6	7	8	9
Revolutions per minute ...	30	26	24	20	18	18
Diameter of runners inches	24	30	36	39	42	42
Width ,, ,, ,,	9	11	13	15	17	18
Approximate weight each cwts.	6	11	16	21	27	30
Diameter of pulley ... inches	18	24	30	36	42	42
Width ,, ,, ... ,,	4	5	6	6	6	6
Revolutions per minute ...	120	104	96	100	90	90
Output per hour cubic yards	4 to 7	6 to 10	10 to 14	14 to 18	18 to 25	22 to 30
Approx. weight Fig. 5102 tons	2¼	3¼	4½	5¾	7½	8¾

DIMENSION OF SUITABLE ENGINES AND BOILERS.

Diameter of pan ... feet	4	5	6	7	8	9
,, steam cylinder inches	4½	5½	7	8½	10	10½
Length of stroke ... ,,	8	9	12	15	20	20
Height of verticle boiler feet	5	5½	6½	7½	9	9½
Diameter ,, ,, ,,	2¼	2½	2¾	3¼	3¾	4
Number of cross tubes ...	1	1	2	3	4	4

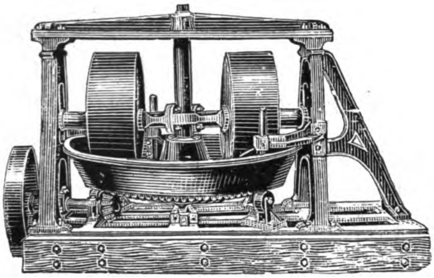


Fig. 5102.

MORTAR MILLS WITH UNDERDRIVEN REVOLVING PAN.—The familiar type of belt driven mill illustrated by Fig. 5102, is entirely self-contained and ready for fixing on suitable foundations. The cost of accessories is given, and attention is directed to the advantage of wrought iron mill spindles referred to in the foregoing description ; also to the reduced cost of foundations for mills with bed plate of box section.

Portable mills of this construction are mounted on a steel under-frame with four-flanged wheels. If fitted with plain wheels, locking plate and shafts, as shown in Fig. 5103, the extra cost is £4 to £6.

Details of proportion of parts, driving power required, and approximate output are given in the preceding tables.

PRICES OF BELT-DRIVEN MILLS, FIG. 5102.

Diameter of pan ... ... feet	4	5	6	7	8	9
Price of mill	£29	£36	£45	£60	£86	£97
,, ,, on timber frame	£32	£39	£49	£66	£93	£105
,, ,, box bed	£32	£40	£49	£65	£92	£103
,, portable mill with steel frame and wheels	£39	£47	£57	£72	£101	£113
Extra for loose pulley	24/6	28/6	39/-	46/-	54/-	55/-
,, outer bearing	18/-	19/-	20/-	21/6	23/-	24/-
,, wrought-iron spindle	22/6	30/-	34/-	41/-	45/-	47/-
,, power hoist (see Fig. 5103)	£11	£13	£15	£17	£20	£21
,, concrete scraper blades		19/-	20/-	22/-	25/-	27/-

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

MILLS WITH OVERHEAD DRIVING GEAR.—If this arrangement should be more convenient than that illustrated, the bevel wheel is keyed on the top of the mill spindle, above the frame, the driving shaft with pinion, pulley, etc. being carried in bearings fixed to the side frames.

In other respects the mills are as above described and cost from £5 to £10 more than under-driven mills.

MILLS WITH ENGINE, BOILER, &c., as represented by Fig. 5103, are fixed on a steel under-frame, with or without friction hoist. The boiler is of the cross tube type and is provided with all usual fittings and connections and arrangements for detaching the driving gear to pan when the engine power is required for other purposes. The dimensions of parts of mills, engines, etc. will be found at page 139.

The hoisting winch is driven by power transmitted from the engine, and the lever for this motion is conveniently placed for working. The price being stated separately the cost of the mill can be ascertained, with or without this accessory.

Portable mills are mounted on four plain or flanged travelling wheels and if locking fore carriage and shafts are required the extra cost is about £4 to £6. Fixed mills are, of course, without these accessories.

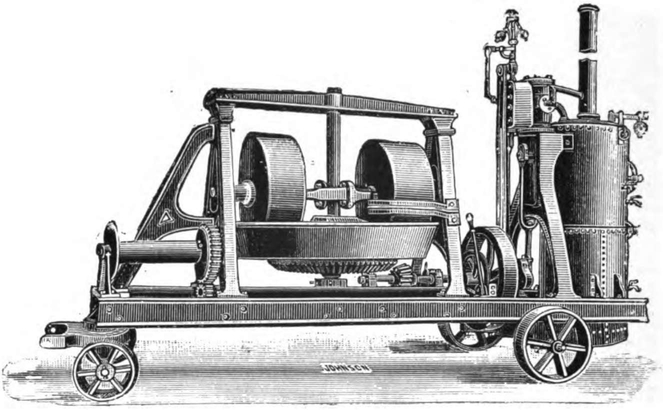


Fig. 5103.

PRICES OF MILLS WITH ENGINE AND BOILER.

Diameter of pan ... ... feet	4	5	6	7	8
Price of portable mill... ...	£96	£114	£138	£178	
,, fixed ,, ...	£89	£105	£128	£168	£248
Extra for hoisting winch ...	£10	£11	£12	£14	£17
Approximate weight ... ... tons	4	5¼	7	10¾	13½

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

MORTAR MILL WITH ENGINE ONLY.—The arrangement is as illustrated by Fig. 5103, excepting that the engine is fitted to take steam from an existing boiler, and neither the vertical boiler or length of bed for carrying it are provided. The foregoing descriptions and prices of accessories apply equally to these mills.

PRICES OF MILLS WITH ENGINE.

Diameter of pan ... ... feet	4	5	6	7	8	9
Price of portable mill	£67	£80	£94	£114	£173	£198
,, fixed ,, ...	£60	£72	£85	£105	£163	£188
Approximate weight ... .. tons	3	4	5¾	7½	9¼	11

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

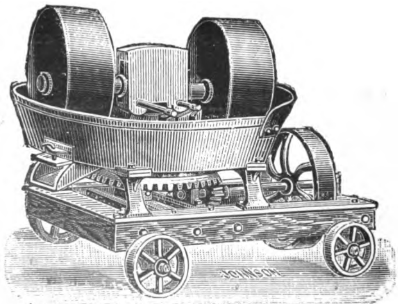


Fig. 5104.

MORTAR MILLS WITH STATIONARY PANS.—Fig. 5104 represents one of the combinations of these mills, and the subjoined information furnishes data for estimating the capacity and cost of fixed or portable mills of any size usually made, with or without engine, boiler, winch, etc.

Edge-runners.—Provision is made for the rise and fall necessary for maintaining uniform crushing and mixing capacity, and the following table gives the standard dimensions and weight of each runner.

Scrapers and delivery.—The scrapers are easily adjusted to suit any materials, and a sliding door with shoot is provided for bottom discharge, if desired.

PROPORTIONS OF STATIONARY PAN MILLS.

Diameter of pan	feet	4	4½	5	5½	6	7
Revolutions of mill shaft per minute	...	24	22	21	20	19	16
Diameter of runners	inches	30	32	36	36	39	42
Width of runners	,,	8	8	9	10	11	13
Approx. weight each	cwts.	8	9	11	13	16	21
Diameter of pulley	inches	18	18	24	24	30	36
Width of pulley	,,	4	4	5	5	6	6
Revolutions per minute	...	102	94	89	85	80	80
Approx. weight	tons	2	2¼	3	3¼	4	5¼

DIMENSIONS OF SUITABLE ENGINES AND BOILERS.

Diameter of pan	feet	4	4½	5	5½	6	7
,, steam cylinder ...	inches	4½	5	5½	6	7	8¼
Length of stroke	,,	8	9	9	9	12	15
Height of vertical boiler ...	feet	5	5	5½	6	6½	7½
Diameter ,, ,, ...	,,	2¼	2½	2½	2½	2¾	3¼
Number of cross tubes	...	1	1	1	2	2	3

STATIONARY PAN MILLS, UNDERDRIVEN.—Fig. 5104 represents a useful arrangement, but prices are also given for mills with cast-iron frame ready for fixing to timber or other foundation.

A loose pulley is always convenient and should be provided for mills which are only used intermittently. The cost of this and of the extra length of shaft, etc. is stated below. If a bearing is required for the outer end of the driving shaft, the cost will be about 20/- to 23/-

The output is about the same as that of mills with revolving pan of equal diameter, see page 140.

PRICES OF UNDER-DRIVEN MILLS.

Diameter of pan	feet	4	4½	5	5½	6	7
Price of mill ready for fixing ...	...	£28	£31	£34	£38	£42	£55
,, ,, on timber bed ...	...	£30	£34	£37	£42	£46	£60
,, ,, with wheels & axles as Fig. 5104		£37	£40	£45	£50	£55	£69
Extra for loose pulley	...	24/6	24/6	28/6	28/6	39/-	46/-
Approximate weight	tons	2	2½	3	3¼	4¼	5¼

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

STATIONARY PAN MILLS WITH OVERHEAD DRIVING GEAR have side frames and cross tie similar to that shown in Fig. 5102, and cost from £5 to (about) £10 more than the last named under-driven mills.

MILLS WITH ENGINE, BOILER, &c.—The machinery is fixed on a frame built of steel girders as represented by Fig. 5103, and is arranged for attaching to a masonry foundation, or is mounted on travelling wheels as required.

PRICES OF STATIONARY PAN MILLS WITH ENGINE AND BOILER.

Diameter of pan ... feet	4	4½	5	5½	6	7
Price of portable mill ...	£95	£105	£112	£122	£135	£172
,, fixed mill	£87	£96	£103	£113	£125	£162

PRICES OF STATIONARY PAN MILLS WITH ENGINE ONLY.

Diameter of pan ... feet	4	4½	5	5½	6	7
Price of portable mill ...	£62	£68	£74	£81	£88	£106
,, fixed mill	£56	£62	£66	£74	£79	£98

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

HORSE-POWER MORTAR MILLS with stationary pan are made with one edge runner and one draw pole for cattle power, or with two runners and two draw poles.

PRICES OF HORSE-POWER MILLS.

Diameter of pan ... feet	4	4½	5	5½	6	6½
Price of single runner mill ...	£16	£18	£20	£23	£26	£30
,, double ,, ,, ..	£21	£24	£27	£31	£36	£42

PORTABLE ANIMAL POWER MILLS.—The mill as last described can be mounted on a steel undercarriage with wheels, axles, swivelling fore carriage, shafts, etc. at an extra cost of £8 to £10, but are not usually made less than 5-ft. diameter.

MILLS WITH GRANITE RUNNERS, Etc.—If the substances to be treated are deteriorated by contact with iron, the edge runners or bottom of the pan, or both, are made of granite.

MILLS FOR MIXING LOAM, SAND and other materials are constructed as shown in Fig. 5104, but runners with a series of webs on each side of a centre plate which lift and thoroughly incorporate the materials, are substituted for the heavy solid runners used for crushing and mixing.

The prices of these mills are about the same as those given at page 142 for mills of the type, Fig. 5104.

BRICK AND TILE MAKING PLANT, for small installations are dealt with at pages 72 to 78 of Section VI.

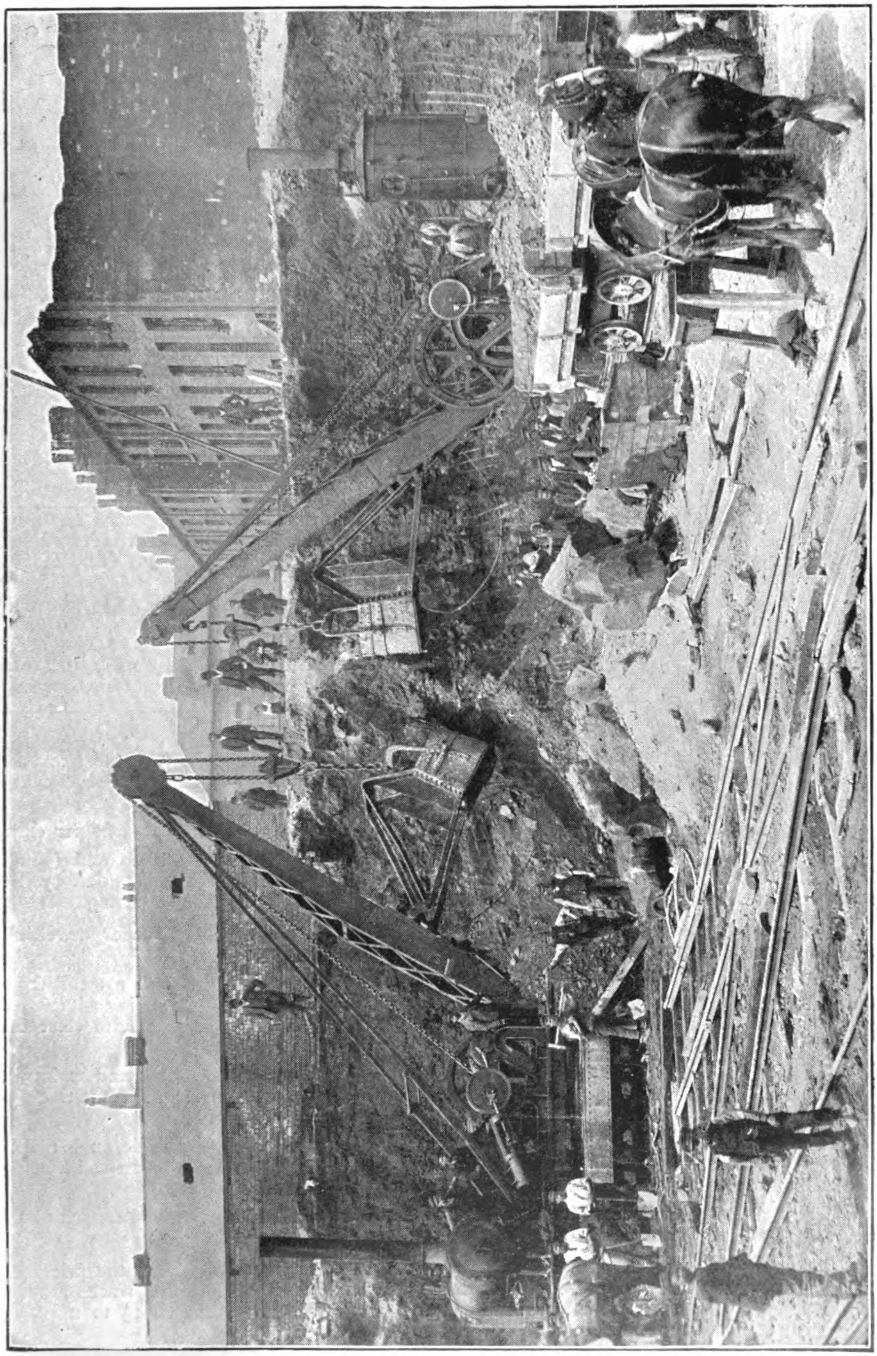


Fig. 5105.

EXCAVATING PLANT.

STEAM EXCAVATOR OR "NAVVY."—The undernamed are the systems of machinery best known and generally employed for quickly and economically excavating all materials, ores, etc. which are amenable to pick and shovel. The spoil is mechanically excavated and deposited in trucks for removal, or on to a travelling belt, and so, without handling, form embankment or tip. In some eases a conveyor of one or other of the types referred to at pages 78 to 83 will be required.

Revolving locomotive steam excavators of the type Fig. 5105, in which the jib and counterweight make a complete revolution in either direction, and will either excavate or deposit at any part of the circle described by the jib.

"End on" steam excavators with excavating bucket similar to Fig. 5105, but which have the machinery, boiler, &c. forming the counterweight, fixed on the undercarriage, the jib only moving through an arc limited to about 90°

Side steam excavators, with dredger buckets and ladder, will travel on rails parallel with the excavation, and are capable of working at a considerable depth below rail level, the position of the bucket ladder being adjustable to work at almost any angle and so form the banks of a river or canal to the slope desired.

Hydraulic excavators are referred to at page 147.

All these machines have been extensively and profitably used under the conditions for which each type is specially adapted, and the revolving or "all round" type has been selected for illustration because it is available for a far wider range of work and has structural advantages which the other machines do not possess.

REVOLVING LOCOMOTIVE STEAM EXCAVATORS are an adaption of the well-known steam crane, and are used as such when the excavating appliances have been removed—the alteration being the work of a few minutes. The length of the jib (about 25-ft. to 30-ft.) is usually simple for fixing girders, large stones &c. The cranes in general use for this purpose are of 5, 7 and 10 tons power. 3 tons crane excavators have been made, but the larger sizes are found to be more economical and durable.

The output in stuff excavated and deposited in trucks naturally varies with the strata in which the machine works, but that from a 10 ton machine is usually about 500 to 1000 cubic yards per day.

A 7 tons machine will give 400 to 800, and a 5 tons from 300 to 700 cubic yards per day.

The railway cutting illustrated by Fig. 5105, consisted of a rather loose and (when excavated) not very hard rock, but sufficiently so to leave the "cleaning up" marks, left by the steel teeth of the bucket, seen on the side of the cutting to the right of the engraving.

The machine consists of a strongly constructed steam crane with motions for travelling and for altering the radius of the jib by steam power.

The excavating bucket is attached to the jib by compensating gear which is controlled by the steam cylinder as indicated in the engraving. This gear holds the bucket up to its work and shortens the radius through which it travels; it also enables the bucket to clear all obstacles arising from falling stones or soil.

The machinery and boiler, which form counterweight, revolve with the jib and maintain the stability of the crane at whatever angle it may be working, relatively with the crane track—a matter of great importance on soft or imperfect roads—as these usually are.

The excavator cuts its own "gullet," and can be set at the most favourable angle; this frequently admits of the machine doing work which must otherwise be done by manual labour. No other machine possesses this facility.

The 5 and 7 tons machines are usually provided with buckets of 1 cubic yard capacity and the 10 tons with 1½ yard buckets.

The working expenses necessarily vary with the nature of the ground, the prices of labour, fuel, etc. but, including the cost of driving the excavator, manipulating trucks around the machine, filling them, superintendence, etc., the cost will rarely exceed 1½ to 2 pence per cubic yard.

APPROXIMATE PRICES OF CRANE EXCAVATORS, Fig. 5105.

Power of crane ... ... tons	5	7	10
Price of excavator	£915	£1045	£1186
Ditto for ditching	£945	£1070	£1228
Approximate weight ... . tons	18½	23	32
Ditto measurement ... cubic feet	1508	1770	2300

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

"END-ON" STEAM EXCAVATORS.—In this machine the boiler and the whole of the machinery, is secured to a strong wrought iron under carriage. The jib is carried by a wrought iron tower, also fixed to the undercarriage and is provided with appliances for turning it, so that the outer end of the jib describes an arc of about 90° which admits of the face of the cutting being excavated within that range and the excavated materials discharged into trucks on either side of the machine.

The arrangement of the mechanism which manipulates the excavating bucket differs from that last described, but, in both cases, it is firmly held to the face of the cutting and is drawn up by powerful gear which causes the bucket to be filled by the time the end of the stroke is reached.

Machines of this type have been used, with excellent results, in almost all kinds of excavation from dry or wet sand to stiff boulder clay.

When working in sand, as many as 640 trucks, or, in all, 2500 cubic yards have been excavated and delivered into trucks in 12 hours by a 10 horse power machine.

The output in highly refractory soil, although much smaller in quantity, is scarcely less valuable. As an example of this, the subjoined figures give the items of the cost of working a machine of 10 nominal horse power when excavating and delivering into trucks 480 cubic yards of very stiff boulder clay in 10 hours.

For convenience in arriving at the actual cost of working the machine and the total cost, under different conditions as regards wages, etc., including manœuvering trucks, laying in roads, shifting the machine forward to the face of the cutting, etc., these items are given separately, and are as follows:—

WORKING EXCAVATOR.

Engine driver per day	£0	5	0
Man manipulating discharge of bucket	£0	4	0
Stoker	£0	2	6
Half-a-ton of coal at 6/-	£0	3	0
500 gallons of water	£0	0	3
Oil, waste, etc.	£0	2	6
Cost of working excavator	£0	17	3

INCIDENTAL WORK.

Man cutting top and breaking down	£0	3	0
Eight men attending trucks, etc.	£1	4	0
Superintendent (ganger)	£0	4	6
Horse and driver...	£0	10	0
Total incidental charges	£2	1	6

So that the total cost was £2 18 9 or rather less than 1½ pence per cubic yard for excavating the above-named, 480 cubic yards, and loading up trucks ready for removal to the tip.

PRICES OF "END-ON" EXCAVATORS.

Horse power of engine	6	10
Price of excavator	£950	£1280
Approximate weight ... ... tons	25¾	35½
Ditto measurement ... ... cubic feet	3270	4280

The cost of packing for shipment and delivery f.o.b. varies, but for purposes of estimate may be assumed to be about 5 per cent.

SIDE BUCKET AND LADDER EXCAVATORS travel on a line of rails parallel with the excavation to be made and are used, with great advantage, where a large quantity of stuff has to be taken out at depths varying from 10-ft. or less to 20-ft. below, or about the same height above rail level. In most cases the buckets deliver the soil direct into trucks; in others it is deposited on a travelling table which conveys it to a tip to form an embankment or for disposal in some other manner.

The engines, boiler and machinery for working the excavating buckets are carried on a strong carriage provided with flanged wheels for travelling on rails, usually 7 to 8-ft. gauge, with an intermediate rail to distribute the weight of the machine over a large area when at work.

The buckets, links and ladder, with top and bottom tumbler similar to those used in floating dredgers, are maintained in the position desired (or the angle is regulated) by chains attached to the ladder and supported by a strut from the undercarriage. The buckets discharge the excavated materials into a hopper behind the machine, the height of which admits of trucks passing under the hopper and being filled from it, a separate line for that purpose being laid behind that on which the machine advances.

Excavators of this type are made usually of from 15 to 45 nominal horse power and will deal with from 1000 to 2500 cubic yards in 10 hours.

The cost of a machine of medium size—25 nominal horse power—is about £2500. An excavator of this power has dredged 2000 cubic yards of sand in ten hours and the working expenses, including fuel and all labour in driving. manipulating trucks, etc. laying in roads, interest on capital and sinking fund was less than one penny per cubic yard of sand excavated and deposited in trucks.

CANAL EXCAVATOR.—The following is a brief description of steam plant which excavates and raises about 150 cubic yards per hour when employed in the formation of irrigation works in tenacious marl.

Excavating machinery.—This is of the ladder and bucket type and is carried, together with the engines, boiler and accessories on a steel girder frame which is mounted on travelling wheels and fitted with springs, end buffers, coupling chains, etc.

Separate engines are provided, respectively, for working the dredger chains and buckets, for raising and adjusting the position of the ladder, and for moving the machine along the track, hauling the spoil wagons, etc.

Work performed.—The ladder works at a right angle with the track through a length of 36 feet and is adjustable to any depth up to 16 feet. The capacity of the machine is 150 cubic yards per hour delivered direct into the spoil wagons.

Working staff.—This consists of one engine driver, one stoker, and one man to attend to the buckets and the loading of the wagons.

TRENCH EXCAVATING MACHINE.—Plant for excavating trenches for drainage, sewerage, etc. is constructed to suit the depth, width, etc. of the work to be carried out, but the following information relates to plant of useful dimensions which is equal to excavating 150 to 160 cubic feet per hour, and forming trenches from 2-ft. 6-in. to 4-ft. wide, of any depth up to about 15-ft. The spoil is automatically delivered into trucks or wagons alongside, and the sides of the trench are timbered in the usual manner, as the work proceeds.

The excavating machinery is mounted on a wrought iron under frame with wheels for travelling longitudinally, and rails to give a cross traverse to a trolly which carries the engine, boiler and all appliances for excavation and delivery.

The soil is removed by ladder and bucket which are provided with arrangements for lengthening or shortening, and for adjusting the angle to suit the work. The spoil is delivered at a convenient height above the top of the trench.

The price of the machine as above described, complete with engine and boiler, steel ladder and buckets for wet or dry work, longitudinal and cross traversing gear and the appliances for automatic delivery, is about £1,100

HYDRAULIC EXCAVATORS.—The machinery can be arranged to travel alongside a waterway, or it can be fixed on a barge for use afloat. In either case the spoil can be delivered at considerable and easily variable distances as described at page 152.

EXCAVATING PLANT FOR DEEP TRENCH IN ROCK.—The following is an outline description of excavating plant employed in recent extensions of the Niagara Falls turbine installation.

Work performed.—A trench 500 feet long and 180 feet deep is excavated out of the solid rock, the sides of the trench being vertical.

Stone channelling machine.—Reference to Fig. 5125 shows that the machine cuts a clean vertical face on each side of the trench, and the rock between the grooves is shattered by dynamite for removal by the cable conveyor.

Cable Conveyor.—The excavated material is removed from the trench by a steel wire rope way supported by towers 600 feet apart, the length between anchorages being 800 feet.

The cable way is two inches diameter, and is central over the line of excavation, with trolleys from which the skips are suspended, and raised or lowered at any desired point in the length of traverse.

The skips are of 2½ cubic yards capacity, and the materials raised from the trench are dumped into steel cars for hauling away; in this case the stone is used in railway construction.

Hoisting machinery.—The engines and hoisting appliances are fixed in one of the towers and are equal to a load of 10 tons; all operations are controlled by one man when working at any point in the length of the traverse or at any depth up to 180 feet.

SAND AND MUD SCOOPS have been largely used in the United States of America and—to some extent—in this country for rapidly and economically excavating sand and soil of various consistencies.

The following description of excavators used in the dock extensions at Keyham is abstracted from a paper read before the Institution of Mechanical Engineers by Mr. Whately Eliott :—

The mud is excavated by means of mud scoops worked to and fro over the site by hauling engines, which are placed on each side of the ground. Those on the outer side are of forty horse-power, and are fixed at the end of an elevated stage, from which the mud is discharged into barges and conveyed by them to sea. Those on the inside are of twenty horse-power and are fixed to travelling frames, and can thus be moved to lead the scoop to such part of the mud as may be required.

The scoop hauled forward over the mud fills itself, the depth to which the cutting edge enters being regulated by adjustment of the hauling chains.

When the scoop is filled, a catch holding the rod on which the chain is coiled is knocked out. The back chain being thus lengthened, the cutting edge is raised clear of the mud, and, in this position, it is hauled over the surface of the mud, up an incline, and along the high level stages until it is over the shoot, where it is turned over by the front chain and the contents are discharged into a barge beneath.

One complete journey is made in 5 to 10 minutes and the quantity carried varies from 2 to 3 cubic yards when the mud is very wet, to a maximum of 5 cubic yards when it is dry.

This installation answered its purpose in preparing the way for wagons which could not have been used on the soft mud, but when sufficiently solid ground had been reached, the rest was excavated partly by hand and partly by steam navvies, the haulage to and fro of empty and loaded trucks being performed by small locomotives of the type illustrated by Fig. 5062. etc.

Excavation in trenches.—The walls for the last-named docks were constructed in timber trenches, the mud being excavated by hand and filled into skips which were lifted by steam cranes, discharged into trucks and conveyed by them to barges for final removal.

Excavation by grab.—In other cases, grabs worked by portable steam cranes are employed with great advantage, the grabs excavating the soil and automatically discharging it at any desired point within the radius described by the jib. The cranes used in connection with grabs of the type Figs. 5109 and 5110, are equally available for lifting skips or for any other service.

DREDGERS AND SUB-AQUEOUS EXCAVATORS.

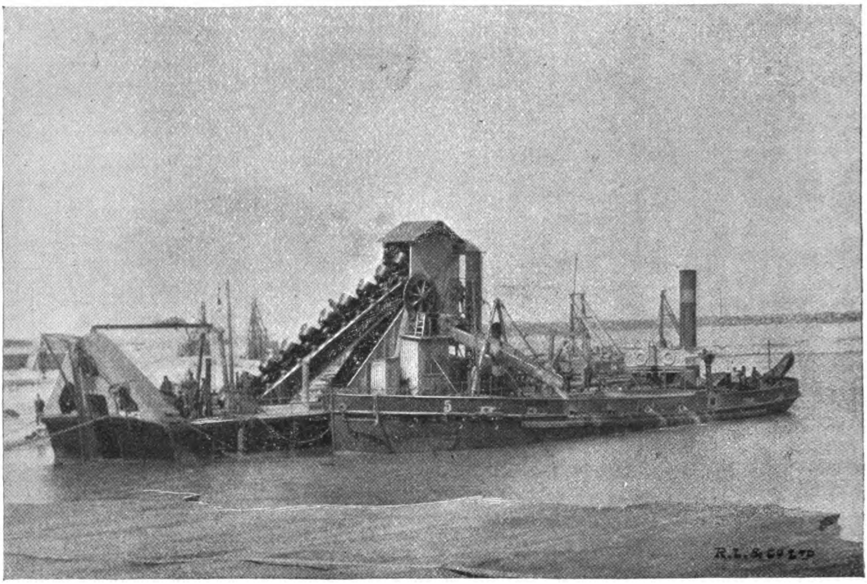


Fig. 5106.

It seems scarcely credible that the modest six-horse power engine, first used by Trevethick early in this century for driving the tumbler shaft of his dredger, should have led to the developments in design, construction and equipment to be found in modern dredgers of the type illustrated by Fig. 5106.

In the limited space available it is impossible to do more than furnish data relating to dimensions, capacities and approximate cost of plant suitable for the conditions mentioned, with some notes on working expenses, etc. but this kind of information may suffice for approximately estimating the outlay for plant to be provided for a given duty.

TYPES OF DREDGERS, WORKING EXPENSES, ETC.—The ladder and bucket dredgers, hydraulic or suction dredgers, and the grab or dipper dredgers, have each their sphere of usefulness, and the following notes relating to working expenses, cost of maintenance, etc. under different conditions, by each system, furnish concise information on those subjects.

NOTES ON COST OF DREDGING.—The average cost of dredging around the British coast, and discharge within a distance of 10 to 12 miles, including all charges excepting depreciation and interest on capital, ranges from 2d. to about 7d. per ton of relatively soft materials, but when working in tenacious ground, raising rock, boulders, etc. the cost increases very rapidly and may be as much as 1/9 per ton, or even more.

COST OF DREDGING IN THE COLONIES.—The following valuable information with reference to the cost of dredging by all known methods is abstracted from the reports for 1898 issued by the Government of New South Wales.

Ladder and bucket dredging in sand, mud and clay cost from 2·05d. to 3·84d. per ton, the average being 2.55d. per ton.

Suction dredging in sand, mud and clay cost from 1·62d. to 3·21d. per ton, the average being 2·4d. per ton, including carrying a portion of the spoil out to sea. The mean cost of dredging alone was 1·78d. per ton.

Combined suction and grab dredging in sand cost from 1·33d. to 3·14d. per ton, the average being 1·95d. per ton.

Grab dredging in sand, gravel, and mud cost from 2·25d. to 4·48d. per ton, the average being 3·73d. per ton. When raising rock the cost rose to 8·57d. per ton.

Depreciation and interest on capital.—These items can be estimated only in relation with individual dredgers and the materials they excavate but obviously, excellence in design, good materials and workmanship go far towards minimising cost of maintenance, and loss in earning power incidental to laying up for repairs.

Maintenance and working expenses.—The late Mr. P. J. Messent, M. Inst. C.E., whose experience in everything relating to dredging was universally recognised, found that the cost of repairs amounts to half the total cost of dredging, the other half being expended in coals 1/12th, wages, stores and general expenses 5/12ths. These proportions of cost do not, however, apply to suction dredgers which are referred to later on, and will not be quite accurate for ladder dredgers working in easy ground.

LADDER AND BUCKET DREDGERS may be divided into two categories, viz. : (1) Dredgers to deliver overside into barge, and (2) Hopper Dredgers which deliver into their own hoppers, and are towed, or navigated by their own steam power to the place where the spoil is to be deposited.

These may again be sub-divided into deep and light draught, and to dredge from both sides, or with single central, or side ladder.

The depth of dredging may range from 5 to 50 feet or more, below water level, and the machinery is built for raising the stiffest clay, boulders, solid or disintegrated rock, gravel, sand, and strata of all kinds down to soft mud.

It may here be mentioned that side ladders are sometimes required for deepening close in-shore, but if work of this kind is not required, a central ladder is usually preferable, with appliances for delivering centrally into hopper or to barge on either side.

Spoil conveyor.—To avoid the expense and loss of time involved in re-handling the spoil, the dredger is provided with conveyors which carry the stuff from the buckets and deposit it in trucks for removal, or on shore for formation of bank.

Details required.—The foregoing remarks indicate the kind and scope of information requisite for proper consideration of the construction and arrangement of plant most suitable for the work to be performed. Restrictions (if any) as to draft or width permissable, should also be stated.

HOPPER DREDGERS are perhaps principally employed in tidal waters where dredging is limited to certain states of tide, the after part of the vessel being fitted with appliances for emptying its own hoppers, also with gear for towing other barges to the point where the spoil is discharged.

PRICES OF LADDER AND BUCKET DREDGERS.—The following data relating to dredgers of different dimensions and capacities may be useful for reference, although (as pointed out elsewhere) it is desirable to have the dredger specially designed for the work it is destined to perform.

Dredger to raise 750 tons per hour and deliver overside, the draught 3-ft. and to dredge to a depth of 22-ft. below water level. The engines compound and surface condensing and boiler of return multitubular type. Also twin screw engines and accessories for propelling the vessel at a speed of about 9 knots per hour.

The approximate cost of the dredger with the usual equipment is ... £26,000

Dredger to raise 750 tons per hour and deliver overside, the draught 13-ft. and to dredge to any depth up to 36-ft. below water level. The engines compound and surface condensing and boiler of return multitubular type. Also twin screw engines and all accessories for propelling the vessel at a speed of about 9 knots per hour.

The approximate cost of the dredger, with the usual equipment is ... £26,000

Dredger to raise 250 tons per hour and deliver overside, the draught 5-ft. and to dredge to any depth up to 45-ft. below water level. The engines compound and surface condensing and boiler of return multitubular type.

The approximate cost of the dredger with usual equipment is £10,600

Dredger to raise 170 tons per hour and deliver overside or to any distance up to 85-ft. the draught 3-ft. and to dredge to any depth up to 22-ft. below water level. The engine compound and surface condensing and boiler of return multitubular type.

The approximate cost of the dredger with usual equipment is £12,000

Dredger to raise 150 tons per hour and deliver overside, the draught 4-ft. and to dredge to 20-ft. below the water level. The engines compound and surface condensing and boiler of return multitubular type.

The approximate cost of the dredger, with usual equipment is £7,800

Dredger to raise 70 tons per hour and deliver overside, the draught 3-ft. and to dredge to 15-ft. below water level. High pressure engine and boiler of return multitubular type.

The approximate cost of the dredger, with usual equipment is £5,750

Dredger to raise 70 tons per hour and deliver overside, or to any distance up to 85-ft. the draught 16-in. and to dredge to a depth of 12-ft. The engine compound surface condensing and boiler of return multitubular type.

The approximate cost of the dredger, with usual equipment, is ... £8000

Dredger to raise 70 tons per hour and deliver overside, the draught 2-ft. 3-in. and to dredge to a depth of 6-ft. below water level. High pressure engine and locomotive boiler.

The approximate cost of the dredger, with usual equipment, is ... £5400

Dredger to raise 70 tons per hour, arranged as last described and complete with stern-wheel propeller, costs about £6450

Dredger to raise 70 tons per hour and deliver overside, the draught 2-ft. 3-in. and to dredge to a depth of 6-ft. High pressure engine and locomotive boiler, and provided with living accommodation and sleeping berths for crew, costs about £5650

Dredger as last described, but complete with stern-wheel propeller, costs about £6700

Spoil conveyor.—Any of the four last-named dredgers can be provided with appliances for delivering the dredge stuff at any distance up to 30-ft. from the dredger.

The extra cost of the conveyor is about £870

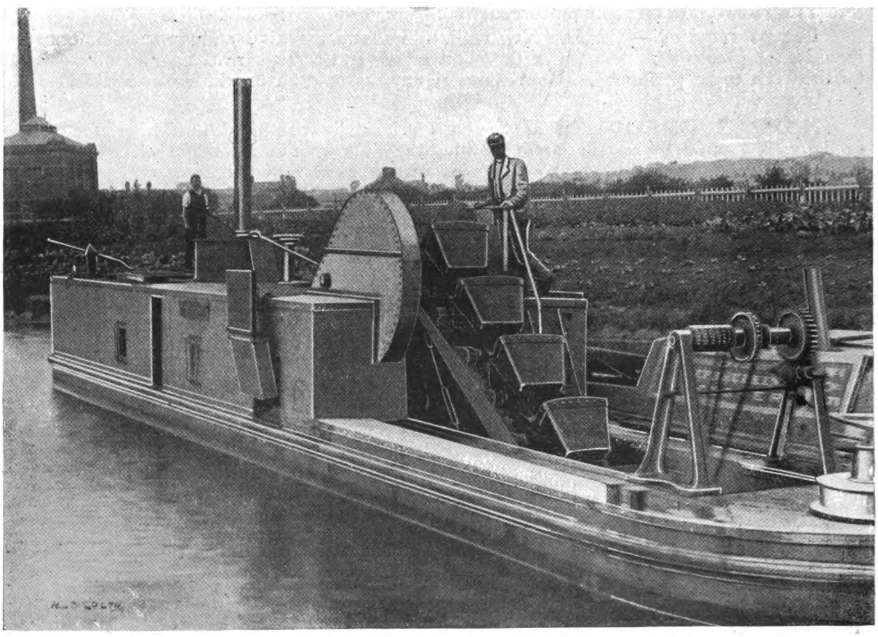


Fig. 5107.

LIGHT DRAUGHT LADDER AND BUCKET DREDGER, for cleansing and maintaining uniform depth in canals, rivers, etc.

The engraving Fig. 5107, represents a dredger to work to any depth up to 7-feet on a draught of 2-feet, and capable of raising 40 to 50 tons per hour.

The engines are horizontal, with link reversing gear controlled by lever at deck level, and the boiler is of the vertical cross tube type.

The plating, angle frames, deck beams, floors and keelsons are of mild steel; the length of the vessel over all is 60-feet, the beam is 9-feet 6-inches, and the upper and lower decking is of pitch pine.

The bucket ladder and buckets are of steel, the top and bottom tumblers are of chilled cast iron, easily renewed, and the bucket links are fitted with loose steel bushes and hardened steel pins. The position of the ladder is adjusted by a self-locking hand winch, and that of the vessel by a steam driven capstan with warping heads of two diameters, respectively for warping and feeding quickly.

The dredge stuff is delivered to either side and the shoots fold back clear of passing craft.

A cabin is provided with lock up hatchway, stove, locker to form a berth, and the coal bunks and tanks carry supplies of fuel and water for two days.

The cost of the dredger with all fair leads, and the usual equipment is about ... £1,750

MACHINERY FOR LIGHT DRAUGHT DREDGERS.—In some cases it is considered desirable to convert an existing vessel, or to build a pontoon of suitable dimensions ready to receive the machinery and many dredgers, which have been in successful operation for years, have been constructed in the manner indicated.

The information required for designing the machinery, and if necessary the vessel to carry it consists principally of:—

(*a*) The nature of stuff to be dredged.
(*b*) The maximum depth and quantity to be raised in a given time.
(*c*) The kind of fuel to be used (if other than coal).
(*d*) Restrictions (if any) in regard to length, width and draft of the vessel.
(*e*) Mode of disposing of spoil.

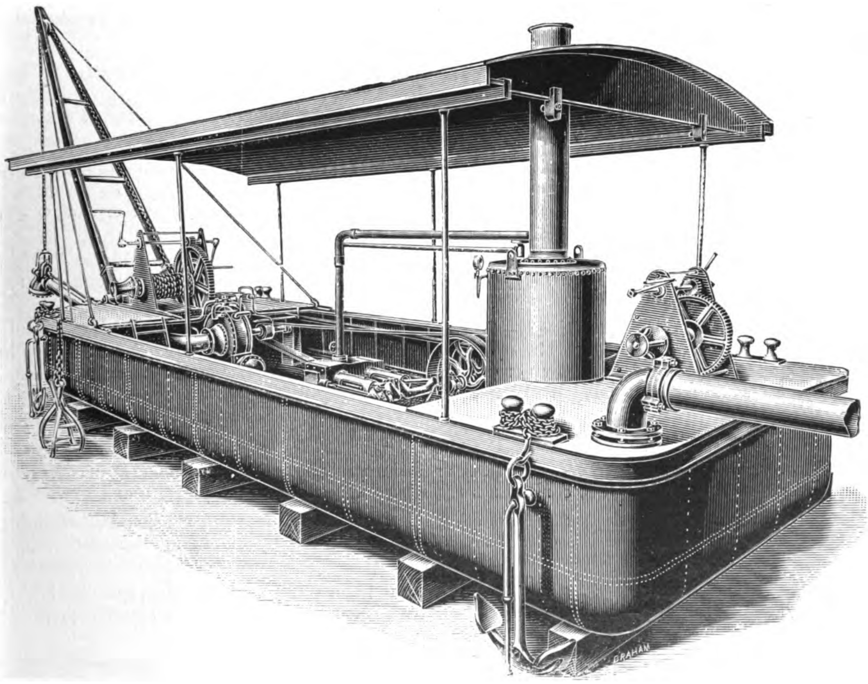


Fig. 5108.

HYDRAULIC or SUCTION DREDGERS.—Fig. 5108 represents a light draught Ball dredger to deliver overside and capable of dredging 100 tons per hour by centrifugal pumps specially designed for this duty. The same type of pump is used for dredgers referred to further on which have raised thousands of tons per hour, and are successfully employed in :

Clearing away bars and sand banks.
Deepening and cleansing water ways, harbours, reservoirs, etc.
Reclaiming land, frequently by direct delivery of dredge spoil.
Ordinary dredging in harbours and in deep or shallow water.
Cutting their way forward on light draught.
Travelling along the bank and delivering spoil in any direction desired.

THE BALL DREDGER, with appliances for classifying or separating has rendered invaluable service in recovering diamonds, gold, tin, and other metals in all parts of the world.

Advantages of hydraulic dredgers.—The machinery is comparatively inexpensive ; it is easily transported and erected and the cost of maintenance is remarkably low. The materials dredged can be raised to any height and carried for deposit at any distance; up to about 15-ft. above water level and 700 feet distance, this can be accomplished in one operation.

Working in rough weather.—The suction pipe can have a flexible connection which admits of dredging being carried on continuously in a swell, or in any weather short of a gale.

Deep dredging.—This system can be used for much greater depths than are practicable with a ladder dredger, as much as 100-ft. being quite feasible with proper construction for deep dredging.

Economy in power.—There is no loss of power in lifting the spoil to an unnecessary height. The same system can be applied for discharging spoil from an ordinary barge.

EFFICIENCY OF SUCTION DREDGERS.—The output capacity of suction dredgers increases very rapidly with the increase in the diameter of pipes. Mr. George Higgins states that, for all practical purposes, the capacity of the suction dredger varies as the fourth power of the diameter of the pipe, the dredgers being in all respects properly proportioned.

Suction dredgers are commonly supposed to be able to handle only very soft materials, but the experience on the Chicago Drainage Canal, and elsewhere shows that, within limits, they work well in almost any kind of stuff.

NOTES ON SUCTION DREDGERS.—The following facts relating to the quantity and cost of work performed by Suction Dredgers—abstracted from papers read before the Congress of the Institution of Civil Engineers (1899) and other sources—indicate some of the conditions under which these Dredgers have been usefully employed.

Removing a sand-bank.—4,309,350 tons of materials were removed in 1898 at a cost of 0·61 pence per ton.

The items of cost are as follows: wages, 0·23 pence per ton ; sundries, 0·25 ; repairs, 0·13 ; total, 0·61 pence per ton.

Cutting channel in sand-bank.—A channel 1000-feet long, 31-feet wide and 2-feet deep was formed in coarse sand in 37 minutes ; the same dredger raised 7384 cubic yards (coarse sand) in one hour.

Tug and dredger combined.—Suction dredging machinery fixed on board the tug boats employed during the (French) operations in Madagascar, was completely successful in increasing the depth of a shallow river (much obstructed by shoals) sufficiently for gun boats, war materials and stores to be towed to the point where they were required for service.

Similar combinations have also been adopted for maintaining a given depth and width of channel, the tug being used for that purpose when not employed in towing.

In clay and hard material, cutters or disintegrators at the suction end of the pipe rapidly reduce the material into condition for passing freely through the pipes to delivery.

Dredging in compact sand.—In another instance part of the work consisted of dredging ground then inaccessible to the dredger. This was reached by extending the suction pipe and dredging through a length of 260 feet.

The materials were discharged into barge and taken out to sea, an average distance of 4 miles at a total cost—including wear and tear, depreciation and interest on capital—of threepence per ton.

The average of the year's work gave an output of 170 tons per hour, and the cost of repairs and renewals did not exceed £60 per annum.

Deepening channel for navigation.—1,308,000 cubic yards have been removed in deepening a channel to 16½-ft. over a width of 656-ft.

The contract price for this work, including transport of the spoil a distance of three miles was sixpence per ton.

Since that work was completed, a suction dredger has been provided which has increased the depth to 18½-ft. and maintains the channel at that depth.

Reclaiming land.—Alluvial deposit and sand have been dredged from a river and raised over the quay a height of 30-ft. for distribution over low laying marsh land at an average distance from the dredger of 335-ft. The land so formed is now used as public gardens.

Maintenance of waterways.—The experience gained on the coasts of this and other countries seems to prove, that recurrent oscillations of large volumes of tidal water in channels which have been dredged to sufficient depth, continue to remove the material brought in by wave disturbance, provided that the channels have been located to profit by this tidal action.

An example of this has been furnished by the removal (by suction dredgers) of 6,325,000 tons of sand in one year, and the maintenance for several years of a depth of water of (practically) 29-ft. over the whole of the area which has been dredged.

As is well-known, the depositing action of winds and waves decreases rapidly as the depth of channel is increased.

Cost of repairs.—The well-known carrying power of water, when travelling at high velocity in a limited area, being utilised in lieu of the mechanism inseparable from other systems of dredging, the wear and tear is so small that the total outlay for repairs on a large dredger (12-in. pipes), in continuous work, did not exceed £60 per annum.

Working expenses.—Examples will be found at page 149, etc. with reference to this important question, but it may be said that the cost of labour, fuel, etc. on a suction dredger used in clearing away a bar or sand bank and depositing in hopper, or into barge alongside, rarely exceeds 1d. to 1½d. per ton of solid matter lifted.

Delivering the spoil on a bank at distances up to 2500 feet costs very little more than discharging into hopper or barge.

Cost of suction dredgers.—The dimensions, draft, arrangement, etc. of floating dredgers vary so widely, that no reliable estimate of cost can be made without complete data relating to the conditions to be fulfilled. That, however, is not the case with regard to the machinery capable of raising a given quantity of sand, or ballast, under ordinary conditions of working.

As already indicated the machinery can be obtained ready for fixing on an existing vessel, or on one built locally, the drawings for which can, if necessary, be supplied in time for the vessel to be ready to receive the machinery when it is delivered.

The following approximate prices include the engine, boiler, dredging pump and machinery necessary for either ordinary dredging, or for raising any of the materials already mentioned.

Cutters for hard ground are sometimes (but rarely) required to loosen exceptionally tenacious ground, and thus largely increase the output of solid matter. The cost of these and the gear for driving them is not an important item, but is not included in the following prices.

PRICES OF MACHINERY FOR SUCTION DREDGERS.

Diameter of pipes	inches	3	4	5	6	7
Approximate output per hour	tons	3	8	12	20	30
Price of machinery	about	£310	£400	£540	£850	£1100
Diameter of pipes	inches	8	9	10	11	12
Approximate output per hour	tons	40	50	65	80	100
Price of machinery	about	£1340	£1700	£2000	£2400	£2600

The cost of packing for shipment and delivery f.o.b. will probably be about 5 per cent.

Vessel or pontoon.—The dredger can be sent out complete as illustrated, or the vessel may consist of a pair of pontoons, with water-tight compartments, bracing ties and timber decking, forming a platform to carry the machinery. The pontoons are usually sent out in segments and marked for bolting together at destination.

In many cases, however, the machinery only is supplied ready for mounting on any suitable craft, sometimes an existing vessel, provided by the purchaser.

If arranged as a Hopper dredger, it can be navigated by its own steam power, and with or without hopper, may be used as a tug for towing spoil barges or other vessels.

Machinery.—This consists principally of a steam or oil engine and a centrifugal pump of the special construction described in the next paragraph, with the necessary suction and delivery pipes, winches, fair leads, etc. All the parts are light enough to be easily transported, and if necessary, the draught may be as little as 14 or 15 inches.

The dredging pump is of the centrifugal type and fitted with chilled cast iron cheeks which can easily be replaced when worn. The blades of the revolving fan are coated with India rubber to resist wear, and provision is made for quickly clearing away obstructions which are carried by the rush of water into the collecting chamber, but are too large to pass through the pipes.

The pump is driven by belt, ropes, or gear, or the pump shaft is attached direct to the crank shaft as may be convenient.

The suction pipe (or pipes) may be at either side, or about the centre of the vessel as desired ; it is raised or lowered, by winch or chain in the usual manner, and carried clear of the water to offer no obstruction when moving to new ground.

The delivery pipes are steel in convenient lengths for laying in any direction and are complete with flanged joints, bolts, etc.

TRAVELLING SUCTION DREDGERS are also built for working on land when deepening very shallow water, raising ballast or minerals, or other sub-aqueous excavation.

The machinery is similar to that last referred to, but it is mounted on a strong trolley to travel on rails, and is arranged to deliver the spoil into trucks, or on the bank to any reasonable distance, in one operation.

For gold and diamond dredging the appliances for separating and classifying are frequently carried on the same trolley, forming a self-contained plant which can be moved to fresh ground when desired.

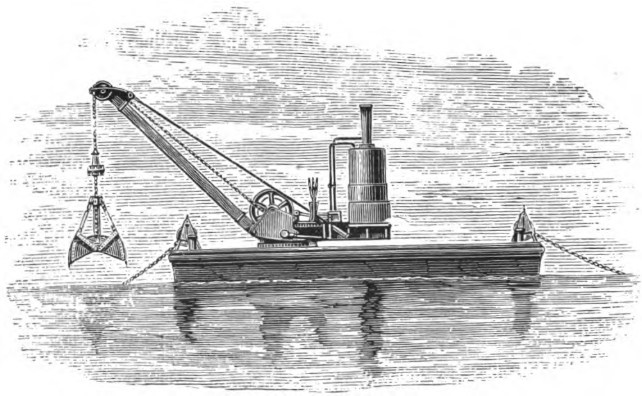


Fig. 5109.

GRAB OR "DIPPER" DREDGERS.—Valuable as these dredgers are for the wide range of purposes mentioned at pages 157 to 159, they can, in no sense, compete with either ladder and bucket, or suction dredgers, for the long stretches of work met with in removing sand-banks, deepening waterways and similar operations.

An installation of the kind illustrated by Fig. 5109, is extremely useful in conjunction with either ladder or suction dredgers when they are working in ground interspersed with boulders, masses of rock, submerged timber, or other obstructions which cannot be brought up by the dredger, but are easily disposed of by the grab and crane.

They excavate to any depth and have done so successfully up to 300 feet below water level ; they are also invaluable for clearing corners inaccessible for any other dredger, or preparing the bed for concrete blocks, etc.

The cost of dipper dredging plant, cranes and grabs, will be found by reference to pages 157 to 160.

The principal item in the cost is a quick working crane which is available for any other duty, and—with the grab—will load or discharge coal, clay, chalk, town refuse, etc. so that the plant need rarely beidle.

Other combinations are illustrated and described at pages 20, 65, etc. as well as in Section II. of this series.

EXCAVATORS OR "STEAM NAVVIES" are referred to at pages 144 to 146.

BARGES for use in connection with dredgers must frequently be of the hopper type. Plain open barges are, naturally, much less costly and are, moreover, eventually available for carrying any kind of materials or merchandise.

The principal objection to their use for carrying spoil has been the cost and loss of time in discharging, but these are greatly reduced by the use of cranes and grabs, or a modified arrangement of the suction dredger.

HOPPER BARGES built in iron or steel, with doors and all appliances for opening or closing them, fitted in place, can be obtained fully marked for re-erection at destination. The plates, frames, etc. are distinctively painted and their positions so plainly indicated, that no difficulty is experienced in rivetting up and completing them, even where skilled labour is not available.

For details required for design see the following paragraph.

IRONWORK AND MACHINERY FOR HOPPER BARGES can also be obtained, together with the drawings necessary for constructing the barges in timber. If drawings are required, the kind of timber to be used should be clearly defined; also the length, beam and draught of water, or the carrying capacity on a given draught; also whether they are to be equipped for towing, for sailing or provided with their own steam power, in the latter case the kind of fuel to be used should be stated.

OPEN BARGES.—The foregoing remarks with reference to the construction of iron, steel or timber barges, to be completed at destination, apply equally to plain open barges for all purposes.

SLIP BARGE to carry and tip large blocks of concrete or stone, for the formation of a breakwater or other structure in "Piérres perdues," consists of a strong water-tight barge with appliances for holding the blocks in place during transit, and for releasing them when they have been towed to the position in which they are to be deposited (Fig. 5001).

They are usually built in timber in the vicinity where they are to be used, but the ironwork, releasing gear, chains, etc. can be supplied, if desired.

GRABS AND SKIPS.

The engravings, Figs. 5109 and 5110 represent respectively portable and floating cranes of the construction best adapted for service with grabs and referred to in the following tables. Both types (of somewhat special designs) will also be seen in Fig. 5043 as employed in cleansing the dock floor and sides.

CRANES AND GRAB DREDGER FOR HARBOUR WORKS.—A combination which has been successfully employed in Harbour construction, is illustrated and described at page 20. This consists of a pontoon with a powerful grab dredging crane at one end and one of 30-tons power at the opposite end which is principally employed in handling concrete blocks; but of course, the capacities and dimensions of machinery and pontoon can be varied indefinitely.

ELECTRIC CRANES AND GRABS.—An example of these is given in Fig. 5040 which shows the crane unloading coal and delivering it to the weighing machine from which it is conveyed by elevators and creepers, without manual labour, to store or bin.

These engravings, however, very inadequately represent the wide range of conditions under which combinations of cranes and grabs are profitably employed, but they may, perhaps, prove, to be suggestive of arrangements which will be equally successful for other purposes.

Construction of cranes, whether steam or electric. It will be seen that there is nothing to impede the drivers view of his work, and that the arrangement of mechanism is that most favourable to upkeep and stability.

Derrick Motion.—Appliances for altering the radius of the jib, at pleasure (see prices of floating cranes), largely increase the facilities for working continuously, without moving the crane or interfering with the grab.

The prices of grabs of the type and capacity required will be found in the following tables :—

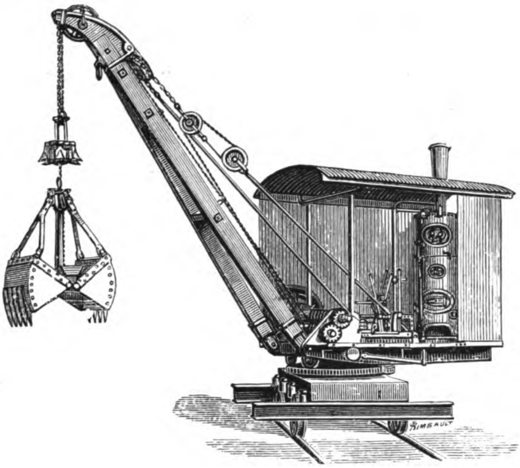


Fig. 5110.

POWERS AND PRICES OF PORTABLE STEAM CRANES FOR WORKING GRABS.

Capacity of Grab	Cubic yards	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{2}$
Lifting power of Crane ...	... Tons	2	3	5	7	10
Price of Portable Steam Crane ...	... ...	£275	£348	£440	£528	£715
Extra for steam travelling motion	... ...	£20	£22	£25	£30	£40
,, steam derrick motion	... ...	£10	£11	£15	£20	£30

FLOATING GRAB DREDGERS (see Figs 5007 and 5043).—Pontoons to carry one or more cranes can be built in iron or steel and sent out complete, or ready for rivetting up at destination, all machinery having been fitted in place before delivery.

In many cases, however, an existing vessel, or one built on the spot in timber, costs very little and probably will answer every purpose.

The dimensions of pontoons vary so widely that the cost must always be specially estimated.

POWER AND PRICES OF FIXED STEAM CRANES FOR PONTOONS.

Capacity of dredger cubic yards	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{2}$
Lifting power of crane ... tons	2	3	5	7	10
Price of steam crane for pontoon ...	£260	£335	£415	£535	£650
Extra for steam derrick motion ...	£10	£11	£15	£20	£30
Extra for propellor and gear	£50	£50	£60	£70	£80

GRAB SKIPS OR BUCKETS.—The great savings in time and in working costs effected by the use of these skips in handling coal, grain, sand ballast, town refuse, and many other materials, are mentioned elsewhere in this volume, and in Section II. (hoisting machinery) from which the engravings have been abstracted for convenience in reference, but the following brief descriptions indicate, generally, (1) the class of materials for which each type is specially adapted ; (2) the probable output per hour ; and (3) the power and appoximate cost of cranes best adapted for dealing with the different sizes of grabs.

Construction.—It will be understood that all the skips are made of steel and are suspended from a single chain or rope; also that the appliances for filling and discharging automatically can be adjusted to any height and are controlled by the driver. The skip and opening gear can be removed in a few minutes, leaving the crane free for ordinary service.

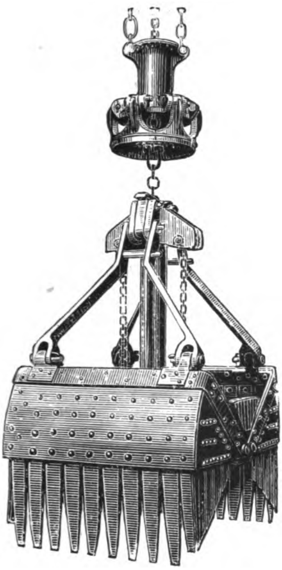


Fig. 5111.

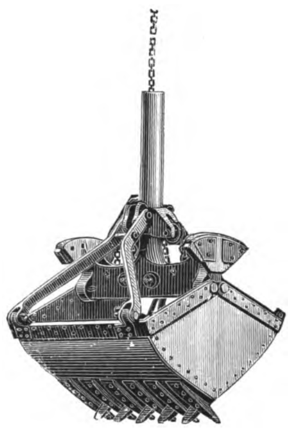


Fig. 5112.

HALF-TINE GRABS.—The construction shown in Fig. 5111 is generally used for excavating in cylinders, caissons, and in clay or other tenacious matter; also for deepening rivers and waterways, removing weeds or other obstructions, raising stones, submerged timber, and so forth.

PRICES OF HALF-TINE GRABS, Fig. 5111.

Capacity in cubic yards	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{2}$
Price of grab	£78	£86	£100	£122	£165
Gear for opening at various heights ...	£8	£10	£12	£15	£20
Approximate quantity raised per hour, tons	12	15	25	35	50
Power of crane required ... ,,	2	3	5	7	10

The cost of packing for shipment and delivery f.o.b. is 5 per cent.

OUTSIDE-TINE GRABS are suitable for working in looser materials than those last referred to, such as sand, gravel or other materials for which a fairly close-fitting bucket is desirable, but which require the penetrative action of the tines, in filling, these overlapping, as shown in the engraving Fig. 5112.

PRICES OF OUTSIDE-TINE GRABS, Fig. 5112.

Capacity in cubic yards	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{2}$
Price of grab	£66	£73	£86	£107	£145
Gear for opening at varying heights ...	£8	£10	£12	£15	£20
Approximate quantity raised per hour, tons	13	20	30	40	60
Power of crane required ... ,,	2	3	5	7	10

The cost of packing for shipment and delivery f.o.b. is 5 per cent.

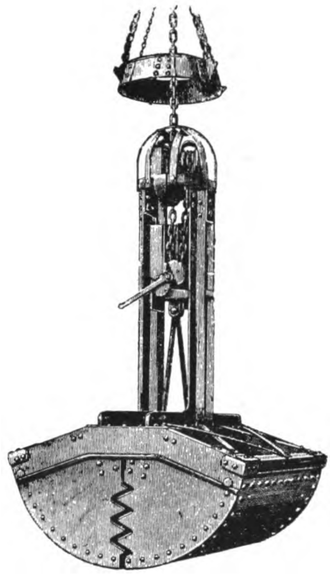


Fig. 5113.

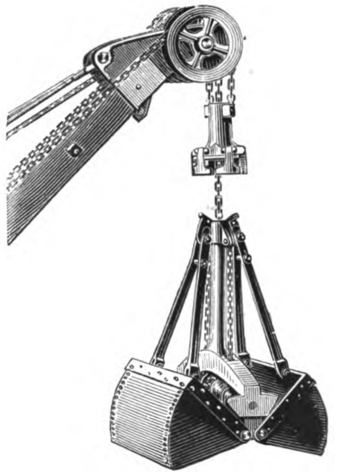


Fig. 5114.

GRAB FOR COAL, COKE, BALLAST, ETC.—Fig. 5113 represents the type of skip specially designed for the purposes mentioned, and for handling other matter which varies widely in bulk and specific gravity.

Work performed.—Millions of tons of coal are every year loaded up or discharged and deposited in store by these self-filling and self-discharging skips, at a cost of less than 1d. per ton. An example of this will be seen by reference to Fig. 5040.

PRICES OF GRAB SKIPS, Fig. 5113.

Capacity of grab ... cubic feet	15	23	30	39	44	78
Price of grab	£78	£95	£100	£118	£129	£185
Approximate weight lifted per hour (coal), tons	20	31	37	45	50	72
Power of crane required ... ,,	3	3	5	5	7	10

The cost of packing for shipment and delivery f.o.b is about 5 per cent.

BUCKET GRABS Fig. 5114.—These are adapted for handling grains, seeds, sand and loose materials, and for raising silt, lowering grout or other matter for which a close fitting bucket is required.

Grab for irregular strata.—A set of light steel tines which can in case of need be bolted to the bucket, Fig. 5114 to increase the penetrative action when working in the (relatively) hard ground sometimes found in sedimentary deposits.

These tines can be removed or fixed in a few minutes, and—at the small cost indicated below—provision is made for working continuously under all ordinary conditions.

PRICES OF BUCKET GRABS, Fig. 5114.

Capacity in cubic yards	⅓	½	¾	1	1½
Price of grab	£56	£63	£72	£95	£130
Gear for opening at varing heights ...	£8	£10	£12	£15	£20
Outside removable tines extra ...	£9	£11	£14	£15	£16
Approximate quantity raised per hour, tons	17	25	35	50	75
Power of crane required	2	3	5	7	10

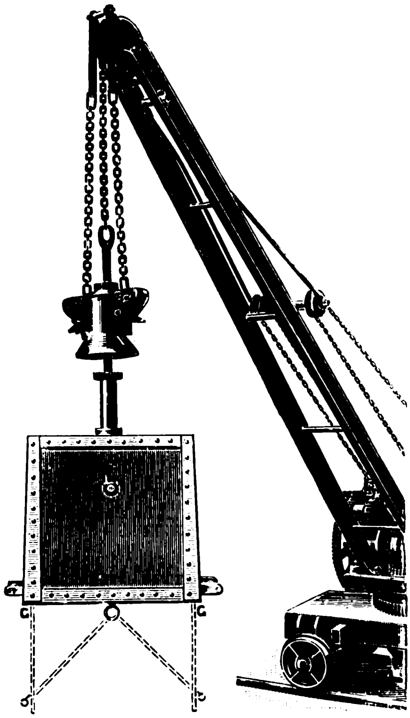


Fig. 5115.

SQUARE DROP BOTTOM (MURRAY) SKIPS, Fig. 5115.—The rectangular shape is preferable, for some purposes, to the cylindrical form described at page 73, but the mode of working is precisely the same in both cases.

They are used for handling many kinds of materials and have done excellent service in depositing concrete under water; the skips for this purpose are usually of ¾ or 1 cubic yard capacity. The opening gear can be adjusted to come into operation at any height desired.

In some cases the top of the skip has been provided with a leather, canvass, or other cover, but the area exposed to "wash" is so small that this accessory is very rarely required.

Opening crown.—Several arrangements for opening the bottom doors have been employed, but that illustrated, which can be adjusted to any height and varied at pleasure, is usually the best.

PRICES OF DROP BOTTOM SKIPS, Fig. 5115.

Capacity ... ... cubic yards	¼	⅓	½	⅔	¾	1
Price of Skip	£8 10	£9 10	£11	£13	£15	£18
,, Opening Gear	£8	£8	£10	£11	£12	£15

PRICES OF ROUND DROP BOTTOM SKIPS, Fig. 5046.

Capacity ... ... cubic yards	¼	½	¾	1
Price of skip	£5	£7	£10	£12
Price of opening gear	£5	£6	£8	£10

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

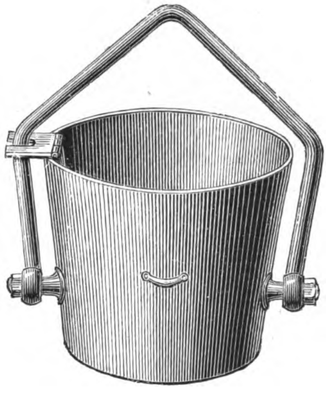


Fig. 5116.

TURN-OVER SKIPS.—This well-known form of skip is made of steel plate, and is kept upright by the catch, as shown in Fig. 5116. When this is released, the bucket turns completely over, but returns automatically to the upright position as soon as the contents are discharged.

The sizes generally used for coal, ore, ballast and similar materials are ¾ cubic yard capacity. Those for grain and matter of low specific gravity are usually of 1 cubic yard capacity, or even more.

PRICES OF TURN-OVER SKIPS, FIG. 5116.

Capacity	cubic yards	¼	½	¾	1
Diameter at top	... inches	27	34	39	43
,, bottom ...	... ,,	23	30	34	38
Depth	... ,,	23	30	34	36
Price of Skip	... ...	£5 4	£6 7	£7 15	£9 0
Extra for swivel eye in bow ...	... ...	£0 10	£0 10	£0 12	£0 15
,, roller and pedestal ...	... ...	£1 0	£1 5	£1 15	£2 5

SELF-ACTING TURN-OVER SKIPS are referred to at page 83.

SIDE-TIP TROLLEY SKIPS, see Fig. 5048.

SPECIAL SKIPS vary very much in size, form and mode of manipulation, but the subjoined notes may be of some assistance in determining the type most suitable for the work to be performed.

Skips for cane, sleepers, etc. are often provided with a simple attachment to secure them to a travelling under-carriage, the skips being lifted by slings at the end of the crane chain with (or without) appliances for tilting and emptying.

Automatic dumping gear.—If large quantities are continuously handled, automatic gear may be convenient, but it is rarely necessary for the above-named skips.

Closed skips for small packages and fragile articles.—Much time, labour and breakage may be avoided by the use of such skips, with efficient lifting appliances, in warehouses, factories, etc.

Open cradles for coal, ore, ballast, etc. are made of numerous capacities and shapes, and are, in some cases, preferable to the types of skips mentioned in the foregoing pages.

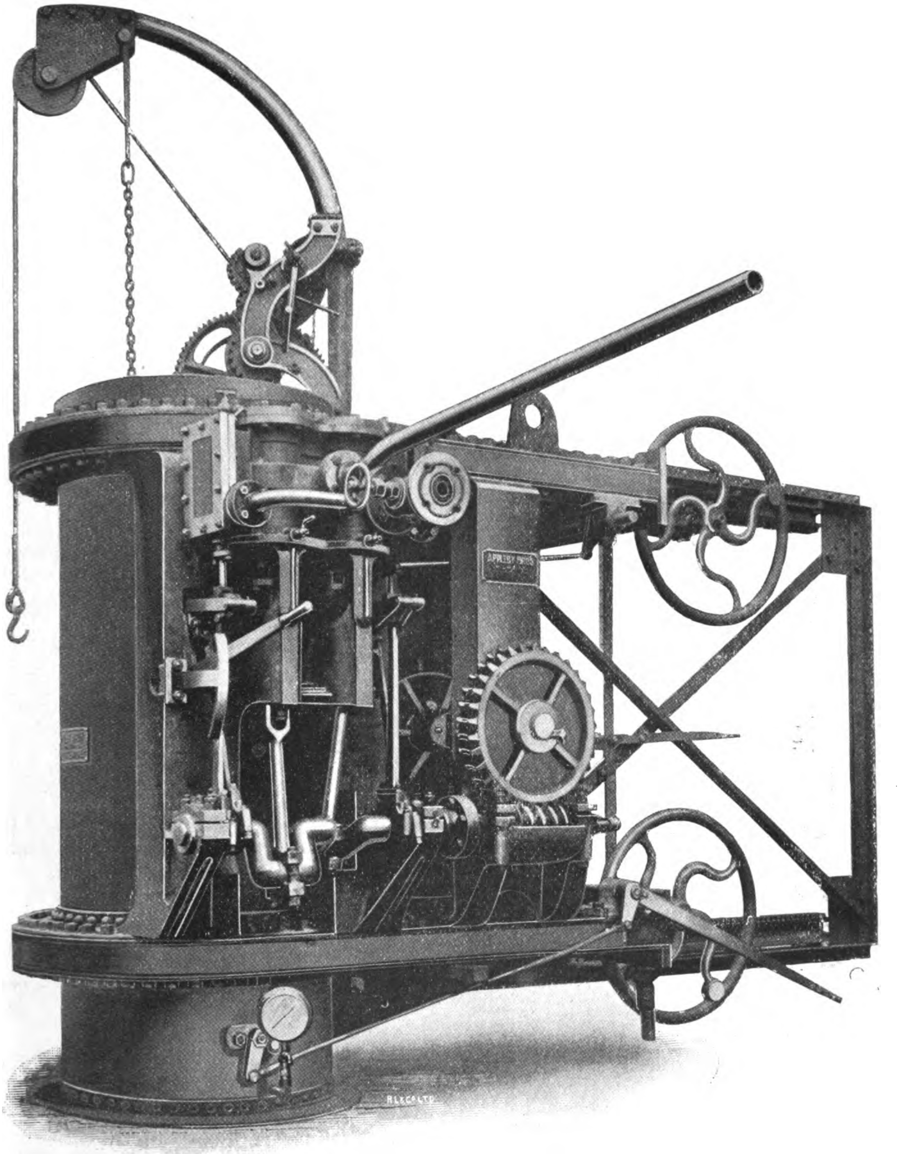


Fig. 5117.

PNEUMATIC CAISSON.—This consists of a wrought iron or steel casing of the length, breadth and depth requisite to enclose the area in which the work is to be carried on, and provided with shafts and air-locks for men and materials. The caisson served by the air-locks, Fig. 5117 and 5118, was 46-ft. long and 13-ft. wide and was used in building foundations for pits at 20-ft. or more below low water.

The lower part of the caisson is constructed to form a strong cutting edge which can enter the ground to be excavated and so tend to reduce the inflow of water.

The upper part is completely covered with air-tight decking with apertures for two shafts which connect the interior of the caisson with the air locks above high water level, one for raising to the surface the spoil which has been excavated—or for lowering materials required in the execution of the works—and the other for ingress or egress of the workmen employed below. All doors are provided with heavy rubber facings which seal the joints and prevent loss of air pressure in the caisson, or shafts.

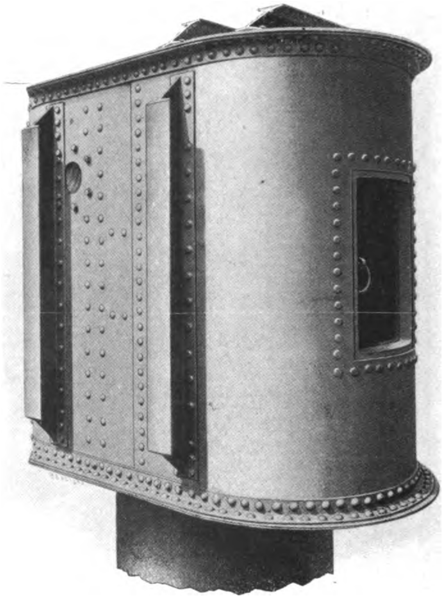


Fig. 5118.

Material lock.—As indicated in the engraving Fig. 5118 a cylindrical chamber is attached to the top of an air-shaft (3-feet diameter) as shown in Fig. 5119. This shaft connects the caisson with the chamber, and the latter is fitted with air-tight doors at top and bottom, with gear of improved design so arranged that neither door can be opened until the other has been closed and locked, so that escape of air in the shaft or caisson is impossible.

Lifting gear.—Materials are lifted or lowered in steel skips which nearly fit the shaft, power for that purpose being transmitted from the double cylinder engines attached to the side of the chamber. So soon as the loaded skip is above the bottom door, this is closed and the top door opened. The skip is then lifted by the curved jib hand-power crane, slewed clear of the chamber, and the spoil tipped into truck or barge.

A steam crane, or derrick crane (Figs. 5037 and 5084) are frequently used for this service, but the appliances indicated were more convenient in this case.

The man-lock, also 3-ft. diameter, differs in arrangement from that last described and is constructed as shown in the Diagram, Fig. 5119, for facility of ingress and egress for the workmen.

The outer chamber is divided into two compartments, and all the doors in both inner and outer chambers are made to close inwards for the double purpose of being completely controlled by the men inside, and for the tendency to keep tight under air pressure.

The workmen coming up the ladder, remain in the outer chamber until the inner door has been closed and they have become accustomed to the difference in air pressure. The outer door is then opened and there is no loss of pressure inside; the sequence of these operations is, of course, reversed for men going down.

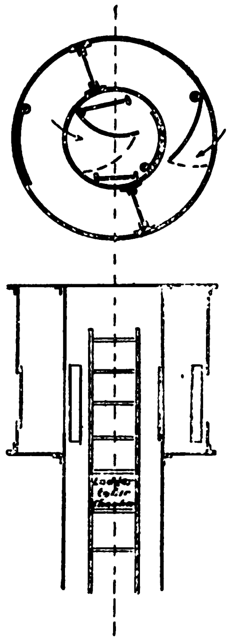


Fig. 5119.

The air compressor supplied with this plant was of the most improved direct-acting type, and was fitted with fly-wheel on each side to maintain even turning movement.

Seeing that cessation or reduction in pressure, for even a very short time, might lead to serious if not fatal consequences, it is imperative that this and all other parts of the plant should be thoroughly reliable.

Steam supply.—The boiler was of the locomotive type, of ample power for supplying steam to the compressor engine and to those on the material-lock, but—in this case as in many others—it was more convenient to have a small boiler alongside the lock-engines, and a vertical boiler was provided for that purpose.

The caisson and shafts can be supplied marked ready for re-erection at destination, but in this instance they were built in the vicinity of the site for the bridge, from designs supplied in advance of the shipment of plant built here. This consisted of :—

The material-lock complete with engines and steam and hand-lifting gear ; top and bottom doors and appliances for manipulating them, all ready to attach to the air shaft.

The man-lock, fitted as described, ready to attach to the air-shaft.

The air-compressor, locomotive boiler, fittings and connections.

SINGLE AIR LOCK FOR MEN AND MATERIALS.—A simple and inexpensive form of pneumatic chamber, suitable for locks of moderate proportions, is indicated in the engraving Fig. 5120.

Construction.—The top plate of the lock chamber is secured to the top plate of the caisson (or cylinder flanges) and is fitted with a flap door at top and a vertical door at side, for access to caisson, as shewn in the engraving. Space is provided for the materials (or a man) to be clear of both doors, and both being easily opened or closed, the necessary facilities are afforded for ingress or egress of men or materials.

The lock chamber is built of mild steel, and the dimensions or form can, of course, be varied to any desired extent, but as a rule it does not need to be more than 5 feet to 5 feet 6 inch deep.

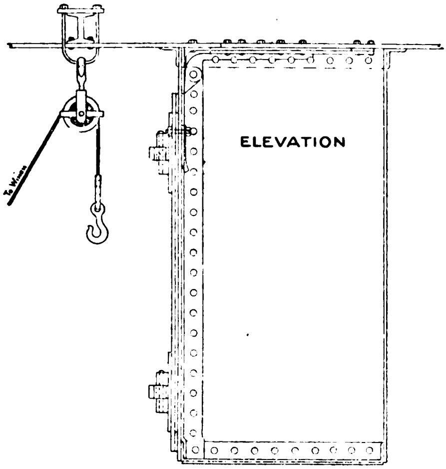


Fig. 5120.

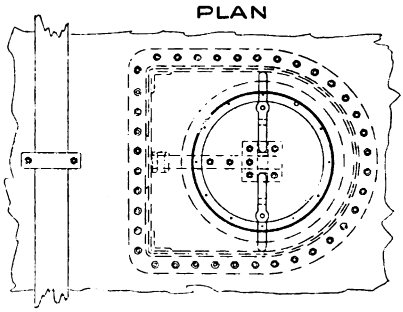


Fig. 5121.

MODE OF WORKING.—A simple winch fixed inside the caisson lifts the materials, and when they have been raised level with the floor of the air-lock chamber, the door is opened and the skip passed inside. The door is then closed and air allowed to escape from the chamber, when the top door lowers and the skip is removed.

COFFER-DAMS AND CAISSONS to form a dam around the area required for the construction of sub-aqueous foundations, are of timber or iron, according to the kind of ground and the depth to be reached below water level.

A timber coffer dam is formed by driving piles around the area to be enclosed, either to totally exclude water so that work may be carried on continuously, or partially so to admit of working at low or half-tide (tide-work). In the latter case sluices are provided to accelerate the outflow of water the rest being pumped out. For pile drivers see pages 42 to 49.

Foundations on rocks, or of great depth below water level, are however usually put in by the (now) well-known pneumatic system, generally useful examples of which are shown in Figs. 5117 and 5118.

DIVING BELLS, see page 168.

DIVING DRESSES AND OTHER DIVERS' PLANT, see pages 166 to 170.

NAVVY TOOLS AND STORES, see pages 128 to 135.

DIVING AND SUBMARINE APPARATUS.

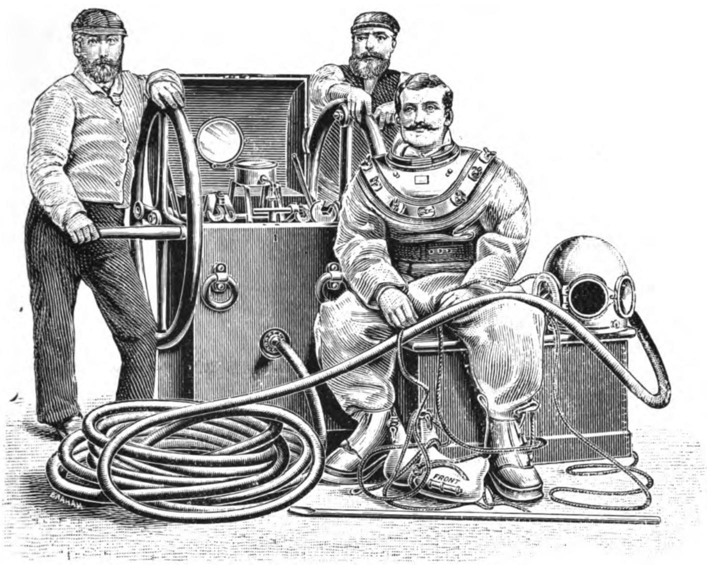


Fig. 5122.

The number of appliances required for efficiently carrying out submarine operations for engineering, salvage, and commercial purposes, is so large that the subject cannot be exhaustively treated within the limits now available, but the outfits referred to below usually suffice for investigations or work in rivers, harbours, and docks, and for examining the condition of ships afloat.

NOTES ON DIVING.—Although the pressure of water—increasing in proportion with the depth—is uniform on the surface exposed, it is well known that the effects on the system, of air at the high pressures about to be referred to, are such that some divers cannot descend with impunity to a greater depth than 80 feet, although others work for a considerable time at depths up to 150 feet, and a depth of 204 feet has been reached by a diver of exceptional strength and training.

The air pressure per square inch of surface exposed is about 8½ lbs. at a depth of 20 feet, 17¼ lbs. at 40 feet, 34¾ lbs. at 80 feet, 65¼ lbs. at 150 feet, and so on in proportion to the increase in depth below water level, and as the pressure to which the diver is exposed causes acceleration in the flow of blood to the head, it is desirable that the speed at which the descent and ascent (especially the latter) is made, should be regulated according to the depth of working and the man's physical condition.

It is scarcely necessary to point out that men of weak habit should not be employed, that divers should be abstemious, and that no food should be taken within at least two hours of commencing operations.

Working hours.—In a good climate the working shift is usually 4 hours, commencing from the time the helmet is fixed, and including about half-an-hour for undressing and resting.

Divers are expected to be in attendance about half-an-hour before their shift commences, for dressing, but arrangements of this kind, length of shift, etc. are naturally modified to suit local conditions.

Maintenance of plant.—The necessity for care and cleanliness cannot be too strongly urged, as well for the comfort of the diver as for the durability of the apparatus.

Diving dresses should be cleaned and thoroughly dried before being put away, and any part which has been cut or frayed by wear, should be at once repaired by the application of rubber solution and prepared canvas, a supply of which should always be at hand. The underclothing will of course be well aired and mended when required.

It is essential that everything should be washed with fresh water and be perfectly clean and dry before it is packed for storage. If this is neglected, damage from decay is almost inevitable.

The air pumps must be kept clean and lubricated, when required, with a mixture of neats-foot and olive oil; no other oil should be used for this purpose.

DIVING PLANT FOR DEPTHS UP TO 60 FEET for one diver consists of the dress with helmet, boots, underclothing, and equipment of air pump, air supply and accessories.

The diving dress is made of two thicknesses of strong double twill with sheet rubber between them, vulcanised india rubber cuffs forming water-tight joints around the wrists, and rubber collar, the boots have lead or iron soles and are protected by gun metal.

The helmet is of planished tinned copper fitted with neck rings to make a water-tight joint, three sight holes with thick plate glass in brass frames, and is complete with lead weights back and front, and all accessories including those which enable the diver to control the supply of air and to return to the surface if, from any cause, the air supply is unsatisfactory.

The equipment comprises a strong leather waist belt and gun-metal pipe-holder, diver's knife in metal case with spring attachments, signal line, helmet pad, helmet spanner and lock-up chest. The underclothing consists of two strong guernseys, two pairs of drawers, and two pairs of stockings (all hand-knitted), woollen caps and twelve rubber cuff rings.

The air supply is provided by a single cylinder double-acting compressing pump, with gun-metal barrel and valves accessible for examination. The pump is surrounded by a copper cistern for water to cool the air supplied to the diver and enclosed in a hard wood case which is fitted with lifting or lashing rings, and carries the gear for working the pump by hand power; a dial gauge indicates the depth at which the diver is working and the pressure of air supply. The air is conveyed by flexible rubber and canvas pipe, with embedded spiral wire, in two lengths of 45-ft. or 90-ft. in all, and the necessary gun-metal couplings.

The price of diving apparatus for a maximum depth of 60-ft. and as above described, is about £65

DIVING PLANTS FOR DEPTHS UP TO 100 FEET for one diver. The diving dress and pump are as last described, excepting that the proportions of the latter are suitable for the increased depth; a larger equipment of underclothing is provided and a strong canvas overall, with tool pockets, to protect the diving dress from abrasion when working in rough places.

The air supply pipe is 100-ft. long in two legths of 50-ft., unless otherwise desired, and is fitted with the necessary couplings.

The price of diving apparatus for a maximum depth of 100 feet is about ... £90

DIVING PLANT FOR DEEP SEA WORK for one man, suitable for salvage work, sponge or pearl fishing and most diving operations, is provided with one helmet and two diving dresses with fittings as last mentioned, but a larger supply of underclothing.

The equipment comprises four woollen guernseys, four pairs of drawers, four pairs of inside and one pair of overall stockings, woollen cap, neckerchief, twelve rubber cuff rings, and 180 feet of signal line. Also rubber cloth and solution for repairing dresses, spare frame for helmet complete with glass and guard and two spare glasses for helmet.

The air-pump has three cylinders with single acting plungers, all of gun metal, two fly wheels on the crank shaft dial pressure and depth gauge, and all accessories. The pumps are enclosed in a hard wood case with lifting and lashing rings, and fitted with spanners for all parts, spare washers for air pipe pumps and helmet, and spare nuts for helmet.

The price of the diving apparatus with three 50-ft. lengths of rubber air pipe and connections is about £120

DIVING PLANT FOR GREAT DEPTHS AND FOR TWO MEN.— There are two complete diving dresses similar to those previously referred to, and two strong canvas overalls.

The underclothing and accessories consist of 6 woollen guernseys, 6 pairs of drawers, 6 pairs of inside and 2 pairs of overall stockings, 2 woollen caps, 2 neckerchiefs, 12 rubber

cuff rings, 2 cuff expanders, protectors for the abdomen, urinals, 2 signal lines each 150 feet long, rubber cloth and solution for repairing dresses, 2 spare frames for helmets with glass and guard, and 2 spare glasses.

Air pumps.—Two gun-metal double-acting pumps furnish an ample supply of air for two divers to work independently at depths not exceeding about 100 feet, but arrangements are provided whereby the full volume of air can be concentrated for the use of one diver at greater depths; all valves are accessible for examination, and the air is cooled and cleansed before it passes into the supply pipe.

The crank shaft is fitted with fly wheel and handle at each end, and a gauge on each pump indicates the pressure of air transmitted and the depth at which the diver is working. The pumps are enclosed in a lock-up teak case with lifting and lashing rings, and tools required for working and maintenance. The pumps are usually worked by two men.

The price of the apparatus with four 50 feet lengths of embedded wire air pipe and connections is £165

DIVING DRESSES AND ACCESSORIES.—The following approximate prices of separate parts of diving equipments may be useful when partial outfits or renewals are required:

	£	s.	d.
Diving dress, strong twill and rubber ...	6	0	0
,, ,, ,, with urinal	6	10	0
Diving boots with lead soles, per pair...	2	10	0
Copper helmet, tinned and planished, with three eyes, shoulder piece, weights back and front, and all necessary valves and fittings	20	0	0
Helmet shoulder piece with screw, nuts, etc.	8	5	0
Helmet pad stuffed with horse-hair	0	5	6
Helmet glasses, each	0	4	6
Screws and nuts for helmets ...	0	3	6
Strong canvas overall coat ...	0	15	0
Air supply pipe, rubber and spiral wire, per foot	0	2	6
,, ,, best floating ,,	0	3	0
Gun-metal couplings, for air pipe, per pair	0	7	0
Prepared canvas for repairs, per square yard	0	8	6
Rubber solution, per 1-lb. tin	0	3	6
Best india rubber cuffs, per pair	0	11	6
Wrist bands, per pair	0	4	6
Wrist rings, per dozen	0	4	6
Bucket leathers, per set	0	8	6

COMPRESSED AIR DIVING BELL.—A steel cylinder about 8 feet high and 6 feet diameter, resembling a portable air-lock as used for pneumatic foundations, has been used for working in 160 feet of water. The bell weighs about 7000lbs. and carries 1000lbs. sinking weights as well as water ballast chambers holding 1000lbs. of water, which can be pumped out in the event of accident to the lifting gear; the sinking weights can also be detached from the inside.

The bell is provided with telephone, electric light, air supply and the appliances required by the men for laying cartridges, fixing grapples, etc. lowered from the derrick boat.

DIVING BELL PLANT.—The bell is rectangular and is now usually constructed of wrought iron or mild steel, with strong suspending chains, provision for cast-iron or other ballast, and fitted with safety inlet valve, top lights, speaking tube or telephone connection to surface, seating accommodation, and electric lights if desired.

The air pumps, air supply pipes and other fittings are similar to those already described, and of dimensions to provide for the absolute safety so essential in all diving apparatus.

DIVING BELL FOR SUBAQUEOUS FOUNDATIONS.—Another successful example of Diving Bell work is furnished in the operations carried out in the removal of concrete block Pier work, which had collapsed, and subsequently in preparing the bed for the wider foundations provided for the new work.

The dimensions of the Diving Bell are: Length, 12 feet; width, 9 feet; height, 6 feet. Four men work in the bell and put the materials excavated into a large box in the middle of the bell. The men can remain below from six to eight hours, and there has been no case of caisson sickness.

Steam winches and other lifting appliances for manipulating diving bells are fully described and illustrated in Section II. of this series.

SUBMARINE LAMPS.—The efficiency and flexibility of the electric light peculiarly adapt it for submarine investigation where the water is clear enough for artificial light of any kind, to be usefully employed.

If current from a dynamo is not available, batteries can be obtained capable of supplying lamps of 20, 40 or 60 candle power for 5 or 6 hours, but supply from a dynamo is, evidently, in every way preferable.

The oxyhydrogen safety lamp, originally invented for exploration in mines, charged with noxious or explosive gases, can also be used for submarine operations.

TELEPHONE FOR DIVERS.—A receiving instrument is fixed in the divers helmet, or in a diving bell, and connected by a light cable with a complete telephone apparatus in a strong case which is placed where convenient. The same apparatus is used with equal advantage for ordinary or submarine service.

DIVING APPARATUS WITHOUT AIR PUMPS.—The diving dress and helmet are similar to those already described, but fitted with connections to a copper cylinder which is charged with compressed oxygen gas. This cylinder is carried on the diver's back and alongside it is a metal box containing ingredients which filter and revivify the breath exhaled by the diver.

The air thus purified is returned to the helmet and re-oxidised by taking up the requisite quantity of oxygen before it is again inhaled by the diver.

The price of the apparatus including helmet, diving dress, boots, cylinder for oxygen, filter and fittings is about £45

APPARATUS FOR PROTECTION FROM NOXIOUS GASES.—The principle of the apparatus is similar to that last described, but a mask and respirator are substituted for the helmet and diving dress, provision being made for filtering and revivifying the exhalations.

Exploration may be carried on with impunity for about four hours in smoke, choke damp or other noxious gases with all the facility afforded by wearing only ordinary dress. The apparatus may also be used for diving to moderate depths.

The price of the mask and accessories is about £20

OXYGEN GAS MAKING PLANT.—The cost of appliances for producing and compressing oxygen gas is about £30

COMPRESSED OXYGEN can be obtained in cylinders containing 30 cubic feet, at a cost of about 6d. per cubic foot.

SUB-AQUEOUS BLASTING.—The under-named appliances will be found useful for a wide range of work, including breaking up wrecks, blasting rock or other matter requiring removal, and the prices being given in detail the increase or deductions for additional or reduced quantities required, can be easily ascertained.

MAGNETIC EXPLODER.—One of the simplest and most easily managed appliances for generating electric current for blasting is the horse-shoe magnet, with armature contact arranged to increase the intensities of current about five-fold, and explode the charge.

The price of the exploder for firing five fuses in circuit, enclosed in lock-up hard wood case, is about £13

Insulated reel for coiling cable, in case with drawer for tools and accessories, costs about £8

The price of the tools, etc. in the drawer, comprising cutting pliers, twisting pliers, coil binding wire, twelve yards of gutta percha covered copper connecting wire, India-rubber tubing, tape and stick of compound is ... ... £1 5s.

Cable covered with rubber and canvas costs about £5 per 100-ft.

The price of fuses for dynamite is about 4/- per dozen.

The cost of packing for shipment and delivery f.o.b. is usually 5 per cent.

SUBMARINE ROCK DRILLING.—Putting down blast holes under water by manual labour is always a slow and expensive operation, if—as is sometimes necessary—it must be done by divers, but both time and cost may be much reduced by using a percussive drill of the type illustrated by Fig. 5137. Other methods of drilling under water are referred to at page 170.

Percussive drill plant.—The drill is worked by compressed air, the compressor and engine for driving it being mounted on an air receiver which is complete with pressure gauge, safety valve, blow off cock, connections for tube for air supply to drill, etc.

Efficiency of sub-aqueous drills.—A Russian authority (Naval Constructor Beliankin) finds that drills driven by compressed air, drilling in granite or other hard substances, work as well under water as in open ground.

The drill is precisely similar to those used in granite and ordinary stone quarries, mining, etc. and is mounted on a strong tripod adjustable for the drill to work at any angle.

The same drill can also be used in connection with a stretcher bar carrying one or more drills, as sometimes required in sinking cylinders, mine shafts, etc.

The price of the drill plant including air compressor and engine, air receiver with fittings and connections, drill with adjustable tripod and weights, 50 feet of flexible special hose with connections to compressor and drill, a set of 20 steel drills and swages for sharpening them, is about £200

The price of a stretcher bar to carry one or two drills is usually about £12

The price of a vertical boiler with cross tubes, chimney and fittings is about £80

DIAMOND ROCK-DRILLING AND PROSPECTING MACHINES are referred to at pages 186 to 189.

AIR COMPRESSORS, RECEIVERS AND PERCUSSIVE DRILLS are illustrated and described at pages 190 to 193.

SALVAGE AND WRECK-RAISING PUMPS.—Information relating to centrifugal pumps, pulsometers, etc. which are principally used for these purposes will be found at page 3 and elsewhere in Section III., but the following approximate prices for centrifugal pumps with vertical direct-acting single cylinder engines may be useful.

The machinery is carried on the base plate which can be bolted to temporary or permanent foundations and is complete with appliances for slinging and handling. The steam supply may be taken from the salvage steamer's boiler or from one specially provided.

The cost of boilers and connections, of all kinds, will be found in Section I.

PRICES OF CENTRIFUGAL PUMPS WITH ENGINE.

Diameter of pipes	inches	6	8	10	12	14	16
Capacity gallons per minute ...	about	550	1000	1650	2400	3250	4300
Approx. price of pump and engine ...		£100	£130	£150	£175	£240	£300
Extra for brass disc		£6	£8	£14	£15	£20	£25
,, brass spindle		£4	£5	£6 10	£7	£8	£10

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

QUARRYING PLANT.

Plant of the most modest character frequently suffices for the earlier stages of quarrying operations, but, as the works develop, machinery is gradually acquired to provide for ascertained wants, and—in the absence of clearly defined plans, drawn up by an expert, for working on a large scale—this is usually the most convenient and satisfactory mode of procedure.

As manual labour forms such an important item in all quarry cost-sheets, and sufficient accomodation for workmen is rarely available in the vicinity of the quarry, it is evident that judiciously selected quick working power plant must yield a good return on the capital invested, by reducing the outlay for labour and largely increasing the output.

The quantity and kind of plant that can be profitably employed depends, of course, on the nature and extent of the workings, but there are few, indeed, where steam cranes and rock drills will not prove to be a paying investment.

Power employed.—Before referring to the machines themselves, it may be well to consider the various modes of applying power which are available under different local conditions.

STEAM POWER, applied direct to the machine, is usually the most convenient mode of driving. There is rarely a scarcity of men competent to drive and stoke, and, until quite recently, scarcely any other mode of driving was contemplated. But difficulties have presented themselves in the writer's experience, such as unsuitable water, or short supply, high cost of fuel when delivered at the quarry, and so forth. Difficulties of these kinds may be overcome by the adoption of alternative modes of driving, such as those about to be referred to.

ELECTRIC POWER.—The great elasticity in transmission of power by electric current, almost regardless of distance or direction, apart from other advantages and economies, referred to elsewhere, render electric transmission invaluable under circumstances where power cannot be provided under favourable conditions (if at all) by other means.

The Cranes and machines employed about a Quarry are driven by electric power just as easily as by steam power, but the Dynamo house, from which the current is conducted by cable or wire may be at any reasonable distance, the motive power for driving the Dynamos being located where supplies of fuel and good water for steam boilers is most conveniently obtained or—better still—where the supply of water is sufficient for working by a turbine or water wheel.

Approximate prices of Dynamos, Motors, Engines, Turbines, etc. of usual powers will be found in Section I. of this series.

GAS AND OIL ENGINES are used with advantage, in some situations, for driving Dynamos, stone-working machinery and air compressor used in connection with rock drills, but they have not hitherto been successfully applied to cranes or portable machines.

Approximate prices of such engines will be found in Section I. of this series.

ROCK DRILLS, driven by steam direct or by compressed air, are illustrated and described at pages 185 to 193, so that it will only be necessary to say here that drills worked by steam supplied direct from the boiler give perfectly satisfactory results in open quarries and cuttings. If one or two inexpensive vertical boilers are provided for service with drills to be used in isolated places for opening up, etc. they will often save the cost and inconvenience of long lengths of steam pipe. Such a plant costs much less than an installation for working by compressed air, but this system is in every sense preferable, if not absolutely necessary, for working in headings, tunnels, deep shafts, or other confined spaces. Some notes hereon will be found at page 190, and prices of Boilers, tubes, etc. in Section I.

SAFETY DERRICK CRANES similar to those illustrated by Figs. 5084 and 5124, are effective over the greater portion of an area of 100 to 120 feet diameter; if fixed in a central position this frequently answers every purpose in the earlier stages of development, and the crane is so easily moved, that there is no difficulty in following up the workings, and re-fixing it where desired. The engraving at page 174, represents a useful type of steam crane for quarry and building operations. The jib is 50 feet long, and the lifting power 10 tons.

FIXED AND PORTABLE DERRICK CRANES are built of all powers from 1 to 50 tons, to work by steam, electric, hydraulic or hand power, and with jibs of any length up to about 60 feet.

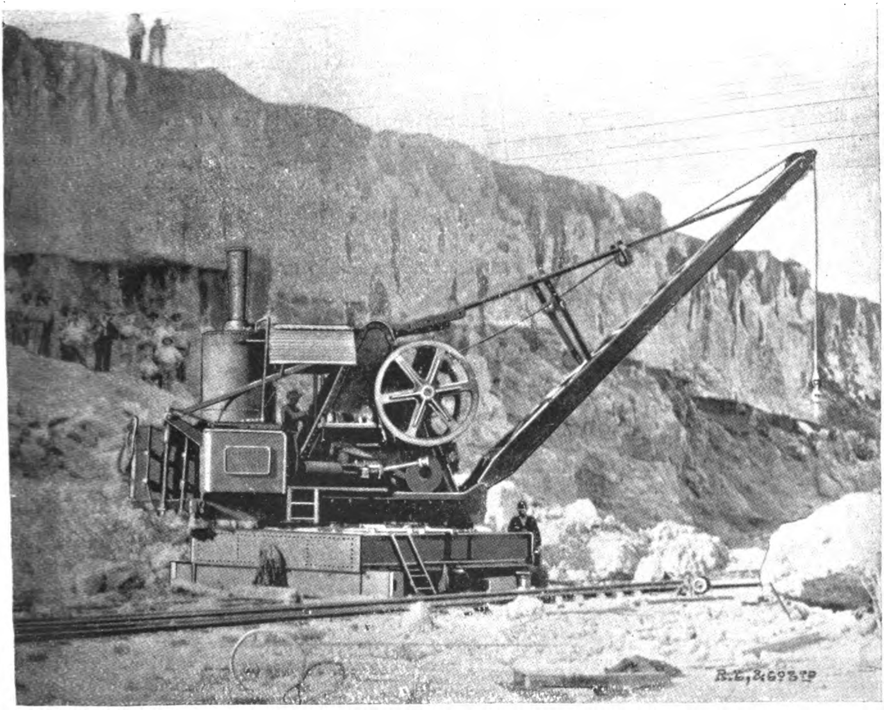


Fig. 5123.

STEAM QUARRY CRANE.—The engraving represents a crane of 25 tons power, having a radius of 28-ft., it was specially built for dragging large blocks of stones out of a quarry and loading them on trucks for delivery.

The proportions, are massive throughout, and a feature in these cranes is, that they can be adapted for any gauge of rails, 3-ft. 6-in. gauge, being, in fact, that of the crane illustrated. Stability on this narrow gauge is provided by the blocking beams which take a bearing at each side of the under-carriage and relieve the track of undue strains; on the narrow gauge the jib must be parallel with the line when the crane is moved.

Special construction.—Many of these cranes are constructed to lift, turn round, alter radius of jib and travel by steam power, all motions being transmitted from the crane engines and controlled by one man; in some cases, however, links connecting the tie rods with the crane sides which gives as shown in the engraving, five variations of radius, are preferred to the mechanism for altering the radius by steam power.

Hauling appliances.—This and other quarry cranes are fitted with appliances for hauling large blocks to a point within the radius of the jib, or for moving the crane itself. This consists of a pair of links, connected with the revolving bed, between which a snatch block is fixed; the lifting chain is carried down the under-side of the jib and is led by a chain pulley at its foot round the above-named snatch block. This gives large hauling power without improper strain on any portion of the structure.

A similar result is obtained by hauling capstans, on one or both sides of the under-carriage. The capstans are driven by the crane engines, but this system is scarcely so elastic and generally useful as that last mentioned.

Handling rubble.—Much useful work is done by a self-acting grab bucket, (see pages 156 to 159), which is attached to the lifting chain, and used for clearing away quarry debris, handling coal or minerals, subaqueous dredging and so forth.

PORTABLE SAFETY DERRICK CRANES.—An extremely useful form of crane for quarries (and for many other purposes) is illustrated by Fig. 5006.

The mast and back tie sleepers being carried on bogie trucks the crane is easily moved in any direction, and the extreme length of jib, frequently indispensable for fixed cranes, is not required.

PORTABLE CRANES of the various types referred to at pages 60 to 65, and in greater detail in Section II. of this series, become absolutely essential in large quarries, for clearing up debris, loading quarry trucks, railway wagons, etc. If fitted with locomotive gear—as most modern steam cranes for quarry use are—they render invaluable service in hauling, as well as in loading and discharging all kinds of rolling stock. The engraving Fig 5036, illustrates a crane of 5 tons power, to lift, slew, alter radius of jib and travel by steam, for which a gold medal was awarded at the Paris Exhibition of 1900.

Prices and engravings of portable cranes of various types and powers will be found at page 60.

The power of Quarry Cranes is usually 5, 7 or 10 tons, but the tendency in recent years has been in the direction of larger powers up to 25 tons (as illustrated at page 172) or more; these, however, it should be noted, require a specially good road and heavy section of rails.

GOLIATH CRANES.—Quarries producing large blocks can usually find profitable employment for one or more fixed or portable Goliath Cranes in manipulating blocks, loading for transit, etc.

Whether they shall be worked by steam, electric or hand power, is purely a question of convenience, but as cranes of this construction can rarely be at all continuously employed, hand power—which is the cheapest form—frequently answers every purpose.

Illustrations of these cranes will be found at pages 21 to 23, and further information at pages 9 to 17 of Section II.

OVERHEAD TRAVELLING CRANES driven by steam or electric power, by endless rope, longitudinal shaft, and by hand power, have been successfully used in quarries under widely differing conditions.

In most cases one or other of the systems already mentioned, or a combination of them, is preferable to overhead cranes; but the undernamed arrangement, for which the writer is responsible, has been completely successful in several marble quarries.

Description of workings.—The area of ground to be opened at one time for the development and working of the quarries being restricted, a timber gantry about 12 feet high was erected to give a span of 80 feet, a traverse of 100 to 130 feet, and carry an endless rope overhead travelling crane of 20 tons power; this was driven by a portable engine at one end of the gantry. The maximum depth of working, in this instance, was 80 feet.

A rectangular pit is formed between the lines of gantry, and the marble extracted from it is raised by the crane, and traversed to one end, where it is deposited on trucks for transport by temporary railway to the main line, or to the dressing yard connected with the quarry.

As the deposits were exhausted the ground was filled in and made good, and that section of gantry removed for re-erection at the other end.

Other installations, such as overhead rope ways, steam travelling cranes, and driving by longitudinal shaft, have been employed under similar conditions, but on the whole they are scarcely so satisfactory as those driven by electric current or endless rope. The supply of fuel and water for a steam traveller, the escape of steam and the risk of injury to workmen from hot cinders falling in the workings, are drawbacks which are absent when the other systems are used.

WINCHES, CHAINS, ROPES, BLOCKS, Etc. suitable for quarry work are referred to at pages 123 to 126 and 230 to 234.

REPAIRING SHOP, STORES, Etc.—Smiths' hearths, tools, and some steel and bar iron are, of course, indispensable, and a preliminary supply will cost, perhaps, £50 to £100.

If much machinery is used and no local engineer's shop is available for repairs, the undernamed tools will probably effect considerable savings in time and expense.

A sliding surfacing and screw cutting lathe with 8-inch. centres and bed about 12-feet long; a small drilling machine, bolt and pipe screwing tackle and a few fitters tools, spirit level, ratchet braces, movable spanners, pipe cutters, pipe tongs, etc.

The cost of these tools will be about £130

PORTABLE RAILWAYS FOR QUARRIES.—The kind and quantity of light railway plant to be provided, naturally depends on the character of the workings, the length of lead for saleable materials, disposal of debris and many other local conditions. But all experience points to the advantage of having a sufficient supply of track, trucks and other necessary light railway materials; also of rails of heavier section for carrying cranes, and main line or other heavy rolling stock.

When considering the mode of traction to be adopted, it will no doubt be borne in mind that the cost of maintenance of roads is far higher for horse than for locomotive traction, and that the higher speed and greater hauling power of the latter are sometimes of great advantage.

RAILWAY MATERIALS, LOCOMOTIVES AND ROLLING STOCK.— Information on these subjects, the speed and tractive power of locomotives on different gradients, and on other matters connected with light railways, will be found at pages 89 to 109.

STONE BREAKING MACHINES, SCREENS, ETC. for quickly preparing quarry debris for market, are illustrated and described at pages 181 to 184.

STONE AND MARBLE WORKING MACHINERY.—This subject is treated in some detail further on, and the principal object in alluding to it here is to point out the large saving in time, cost of carriage, handling, etc. which is effected by having machinery at the quarry itself for finishing the work to be delivered (if required) at the site ready for building into the walls. The large area indispensable for builders' materials, and the continuous increase in the value of land in central positions, must lead to more and more work being finished at the quarries instead of by the builders themselves, however well equipped they may be.

PRICES OF STEAM AND HAND DERRICK CRANES will be found at page 112. The crane, Fig. 5124, is of 10 tons power.

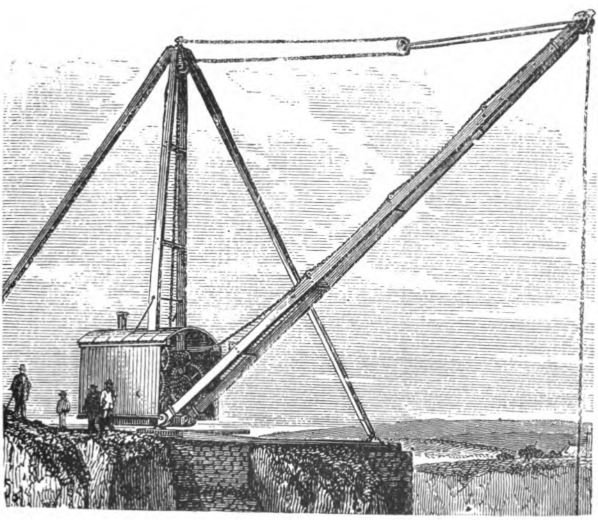


Fig. 5124.

STONE AND MARBLE WORKING MACHINES.

The pioneer stone sawing and dressing machines—although somewhat crude—have rendered good service in demonstrating the great saving in time and cost of working effected by mechanical appliances, and the direction in which improvements could be made; the machines now referred to represent some of the modern types which have been thoroughly tested under continuous work.

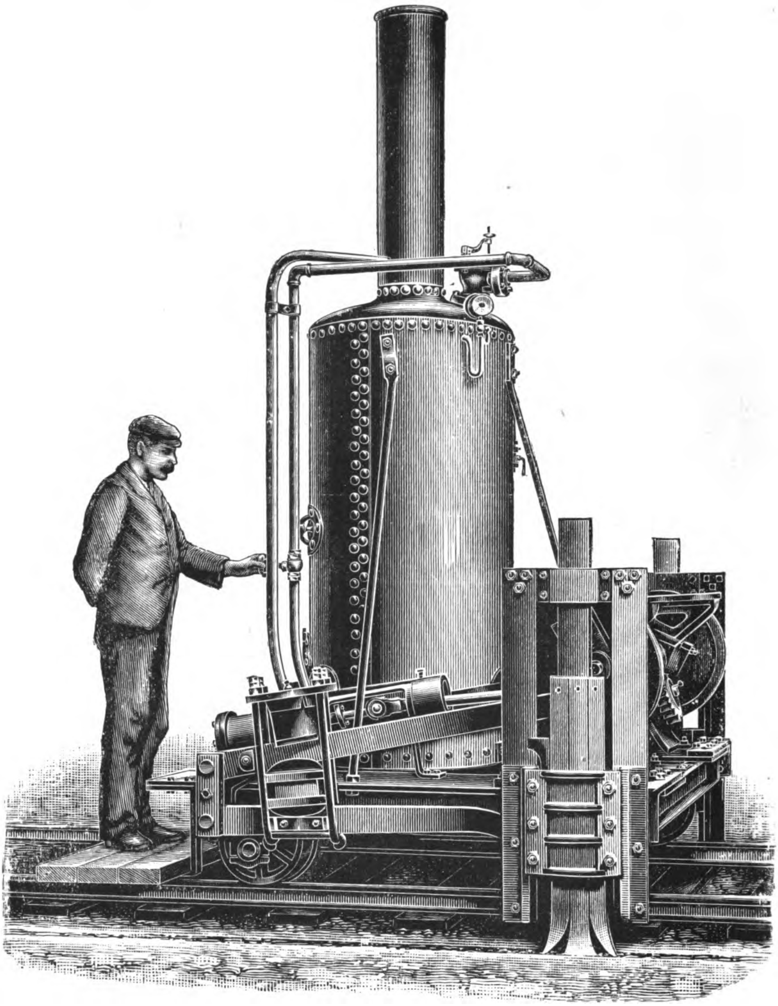


Fig. 5125.

STONE CHANNELLING MACHINES.—Fig. 5125 illustrates a machine which cuts a groove on one or both sides of the track, as desired, and—when working in Sandstone—to any depth up to 6 or 7 feet, leaving a straight and clean cut face similar to that produced by sawing. When both tools are used, the grooves are about 7 feet 9 inches apart, but as already indicated, one side only can be operated, and the machine moved to cut grooves to any width desired. The mean width of the groove is about $2\frac{3}{4}$ inches.

The Machinery is constructed largely of steel, and consists, as will be seen, of a boiler, engines, steel jumpers, and gear for working them, all being mounted on a strong travelling carriage which is complete with all appliances for working and for easy removal to other parts of the quarry. See also article on "Rock Drills."

The price of the machine with jumpers, spanners, lock-up tool chest, driver's tools and 50 to 60 feet of track, is about £330

The weight is about 5 tons, and the cost of packing for shipment and delivery f.o.b. is about 5 per cent.

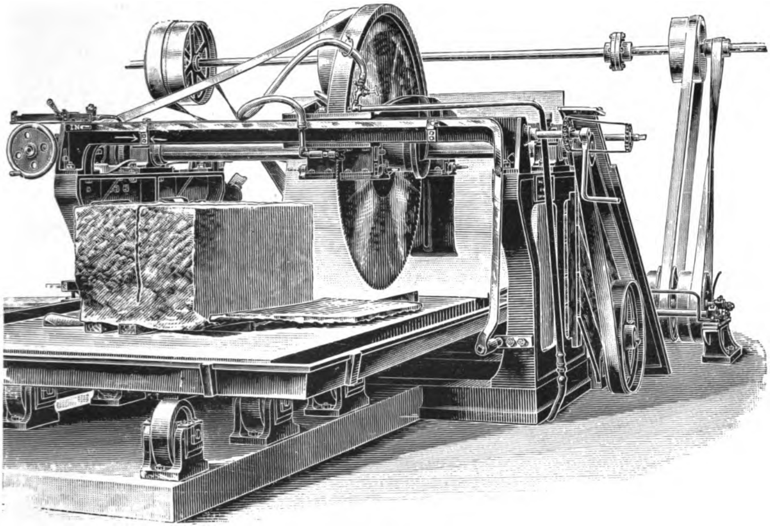


Fig. 5126.

DIAMOND STONE SAWING MACHINE.—The advantages of this system are that there is no discoloration of the stone or marble, and that the wear of the diamonds, which form the cutting surface, is infinitesimal.

The diamond saw.—Black diamonds (Bort or carbonates) are firmly fixed in the periphery circular saw plate, and the saw, saw guides, water supply, etc. are moved along the saw spindle for adjustment for a fresh cut, so that there is no loss of time in moving the stone.

The speed of cutting is easily adjusted within a range of about 2½ inches to 10 inches per minute to suit the kind of rock operated upon.

Thickness of Cut.—This can be varied from ½ inch upwards, and the machine will square or slab, blocks of any size within the maximum dimensions of the traversing table.

PRICES OF DIAMOND STONE SAWING MACHINES, FIG. 5126.

Diameter of Saw ... ... feet	5	6	7
Maximum depth of cut ... ... inches	24	30	34
Price of Machine	£350	£450	£550

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

STEEL CIRCULAR STONE SAWING MACHINE of the well-known type, illustrated by Fig. 5127, divides a block into two or more parts, according to the number of saws used. One man attends to the machine, and it is capable of turning out clean work, ready for polishing, at the rate of about 40 superficial feet per hour.

Machinery.—The saw spindle is driven by double purchase gear with adjustable bearings fitted in strong frames at each side of the travelling table; this is usually about 12 feet long and 5 feet 6 inches wide, the whole being mounted on a massive cast iron bed plate. The table on which the block is fixed has three speeds of feed, and quick return motion for clearing away the work, and replacing it with a fresh block.

The saws are of cast steel and the teeth are easily sharpened when worn; two, three, or four saws are fixed on the saw spindle, as required for the work to be turned out.

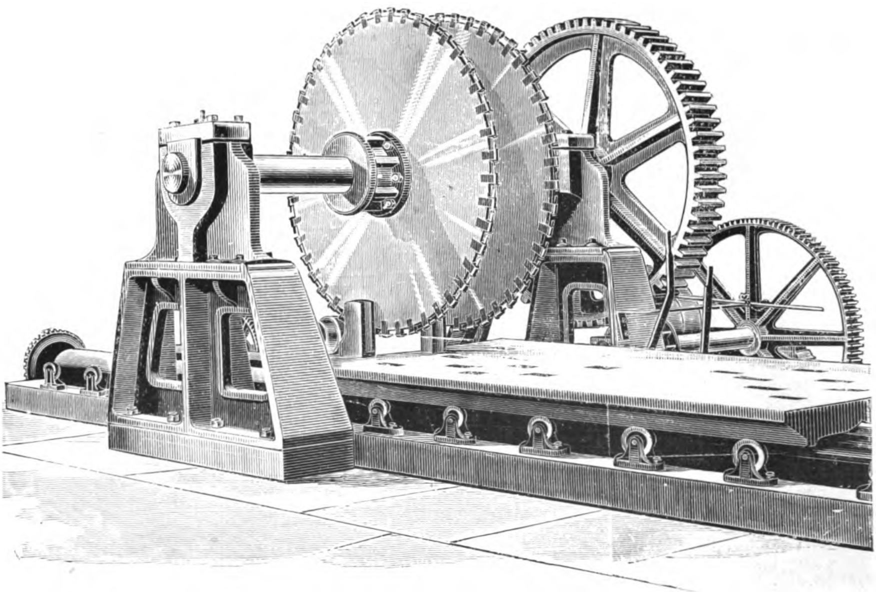


Fig. 5127.

PRICES OF CIRCULAR STONE SAWING MACHINES.

Approximate depth of cut .. inches	9	15	22	30	36
Approximate H.P. required	2	3	4	6	8
Price of machine	£160	£210	£275	£340	£450
Approximate weight ... ... tons	7	10	13½	17	22

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

PNEUMATIC STONE DRESSING TOOLS.—The successful employment of compressed air for working rivetting, caulking and other engineers' tools, has led to the application of the system for dressing and working stone or marble.

The tools are made in various sizes, suitable for the most delicate carving and statuary work, to the heavy cut required for rapidly dressing all kinds of marble and stone, including the hardest granite.

The cost of the tools ranges from £20 to £25

OTHER TYPES OF STONE WORKING MACHINERY.—The foregoing and following engravings and descriptions by no means exhaust the subject, but they represent the standard types of machines which have been largely and successfully employed, and there is little difficulty in designing machinery to fulfil special conditions, if full details are supplied relating to the kind and quantity of work to be performed.

SWING FRAME STONE SAWING MACHINES.—Fig. 5128 represents a machine to occupy minimum space, the working parts balanced to admit of running at high speed, and with bearings protected—as far as possible—from contact with grit, etc.

Construction.—The swing frame is built of steel, and carries saws to cut slabs of any thickness down to one inch. This frame is raised or lowered by steel screws driven by power, but hand gear is provided for final adjustment when commencing a cut. The feed motion is self-acting and can be regulated to give the cut desired.

The inner faces of the columns are planed, to ensure the slide blocks working parallel with each other, and the lifting screws are protected by the flanges of the columns.

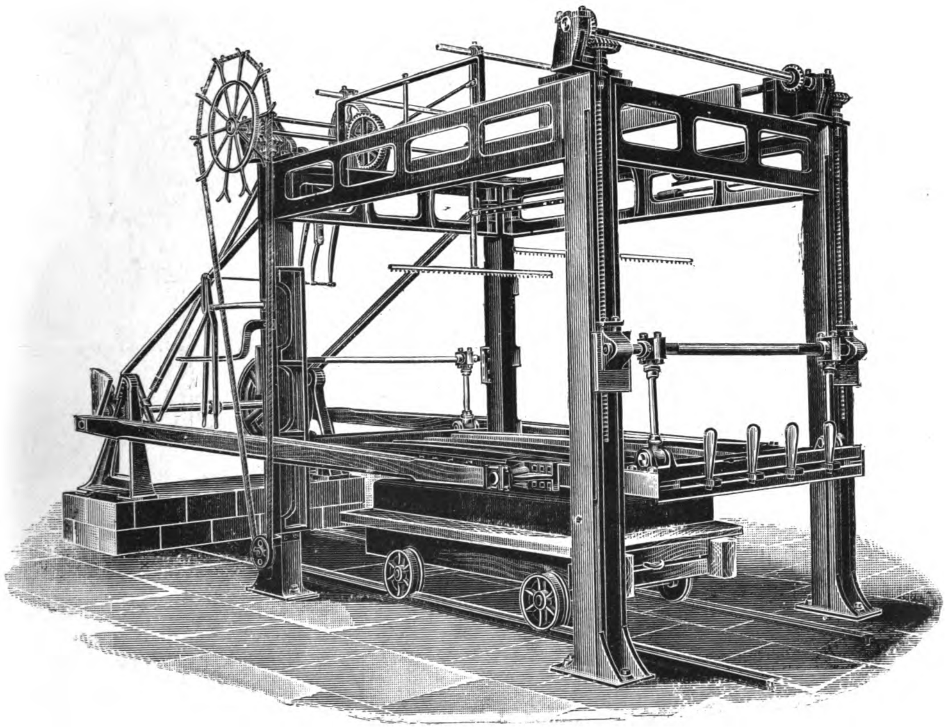


Fig. 5128.

The prices include fast and loose pulleys on the main driving shaft, fittings for water supply, and a stone carrying truck to keep up the supply to the machine.

It is desirable to have a second truck, which can be loaded and immediately replace the work ready for removal from the machine.

PRICES OF SWING FRAME STONE SAWING MACHINE.

Maximum length of cut ... ... feet	8	10	10	12
,, width of cut ... ... ,,	4	5	6	6
,, height of cut ... ... ,,	4	5	6	6
Price of machine	£150	£170	£185	£196
Approximate weight ... ... tons	6	7¼	9	10

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

STONE PLANING AND MOULDING MACHINE.—Fig. 5129 illustrates a machine which, worked by one man, will turn out as much planed or moulded work, of any size within the limits of the machine, as can be done in the same time by 10 or 12 skilled masons, and quite ready for the builder.

The principal features are, that the travel of the table can be adjusted for long or short stones, the cutting tools act in both the forward and backward traverse, and mouldings or other work, fixed on the rocking table which is carried on the main travelling table, can be finished on three sides with one setting. The tool box is moved across the machine by a quick feed screw, and the cross slide is raised or lowered quickly by power, the final adjustment being controlled by hand.

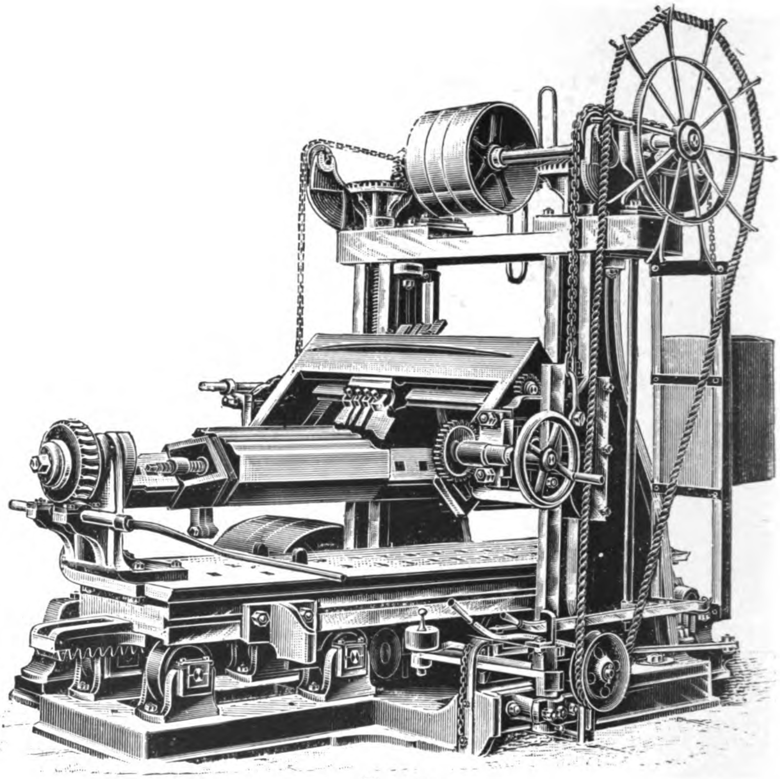


Fig. 5129.

The wear and tear is quite unimportant and the necessary renewals are usually made by the man in charge of the machine, or by a local mechanic.

Sizes and prices.—The dimensions are those to which stones can be dressed to true and clean surface. The approximate prices are for machines of standard dimensions, but these can be increased, or a longer table provided, if required. Any of the machines can be fitted with counter-weight box, and gear for balancing the cross slide, at an extra cost of £15 to £20.

PRICES OF STONE-PLANING AND MOULDING MACHINES.

Length of stone dressed ... ... eet	9	12	12
Width ,, ,, ... ,,	3½	3½	5
Height ,, ,, ... ,,	3½	3½	4
Price of machine	£220	£235	£275

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

MULTIPLE SPINDLE AND RADIAL ARM POLISHING MACHINES,

are not illustrated because they are usually designed and built to suit the sizes, quantity and character of work to be performed, and are very efficient when so constructed.

Information required.—If details relating to the above-named points are supplied, machines can be built which will prove invaluable where a large out-turn is desired.

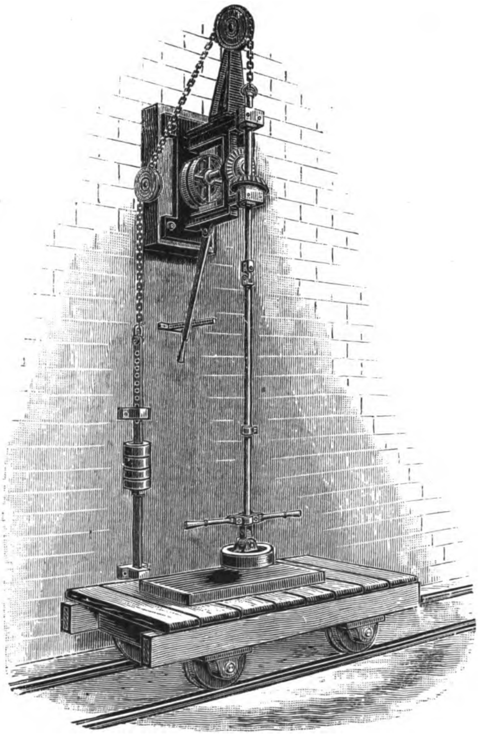


Fig. 5130.

VERTICAL SPINDLE STONE POLISHING MACHINE.—The driving gear is arranged for fixing to a wall or post, as indicated by Fig. 5130; this machine will do as much work as 6 or 8 skilled workmen. Where power is at hand there are few stone dressing yards which cannot profitably employ one or more of these machines.

The price of the machine is £25

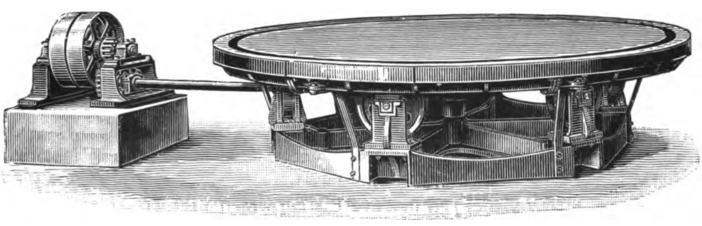


Fig. 5131.

HORIZONTAL STONE POLISHING MACHINE.—The simple, but efficient, machine illustrated by Fig. 5131 consists of a circular table carried on an iron foundation, with gear for rotating the table, as indicated in the engraving.

Mode of working.--The stone to be polished is laid, face down, on the table and held in position by timber framing in the usual manner, the rotation of the table with free use of water and sand, quickly polishing the surface. The overflowing water and grit are collected in the trough surrounding the table and are available for further use.

Work performed—The area polished in a given time is naturally dependent on the character of the materials, but as much as 500 superficial feet have been polished in 10 hours by the medium sized machine.

PRICES OF STONE POLISHING MACHINES.

Diameter of table ... ... feet	8	10	12
Price of machine	£110	£145	£175
Approximate weight ... ... tons	5	7	10

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

CRANES FOR DRESSING GROUNDS.—The advantage of a judicious equipment of cranes for stacking, serving machines, loading up, etc. has long been recognised, and the following notes will indicate (to those who are not familiar with the subject) the types which have given satisfactory results in regard to efficiency and return on capital expended.

Whether the cranes should be worked by manual power or driven by steam, electric, or other motive power depends on conditions too varied to be capable of definition. The writer's experience is, that the first installation of machinery of this kind is usually worked by hand power, but that the increase in demand—resulting from the quick delivery, accurate work and reasonable prices which can be attained by machine work—very often leads to the substitution of steam, or other power, for a portion (if not for all) of the cranes.

Portable goliaths, or overhead travelling Cranes arranged to command a large yard area and—if possible—all the machines, have been found invaluable in many dressing grounds, by reason of the economies effected in manual labour, and time required for handling, and in better utilization of yard space.

Portable jib Cranes are also usefully employed in picking up and loading blocks or finished work, thus leaving cranes of the last named type free for heavier work, which—for various reasons—it is frequently convenient to keep suspended for some time.

Derrick Cranes.—In some yards a fixed or portable derrick crane is employed in lieu of—or in conjunction with—those already mentioned. This system is inexpensive, but does not so completely utilize floor space as an overhead crane.

Swing cranes for machines.—The experience gained in Engineering works has led to the use of inexpensive swing cranes for serving stone and marble working machines.

One crane can often be arranged to place the rough block and remove finished work from two or more tools; and the advantage of the special separate crane is, that it is always available for keeping machines of large earning capacity continuously employed.

Cranes of these types are referred to elsewhere in this volume, and in greater detail in Section II. of this Handbook.

STONE BREAKING AND SCREENING.

Machinery such as that now referred to, for breaking and crushing all kinds of rock, from road metal to emery or the hardest metalliferous ores, being subject to great and constantly varying strains—sometimes exaggerated by careless feeding and neglect in maintenance—are constructed to provide maximum strength, and exceptional facilities for maintenance and removal of parts.

The frame, as usually made, is a massive casting which needs only to be bolted to the foundation; but if the cost of handling and transporting heavy pieces is excessive, the frame is built of steel and sent away in comparatively light parts, which are easily put together at destination, and any of the machines (with or without screens) can be mounted on plain or flanged travelling wheels.

The jaws are made in sections and are easily adjusted to break any size desired. The jaw faces are made of specially hard chilled iron and arranged to be reversed, or renewed, without the aid of a skilled mechanic.

The working parts are principally in steel; the bearings have ample surfaces and are quite accessible for renewal.

Screening machinery.—Simple arrangements similar to those indicated by Fig. 5133. suffice for most of the conditions met with in preparing materials for road metalling, ballasting, and building operations ; but much more elaborate appliances are usually necessary for properly treating ores for classification, slag, coal and many other substances, each of which require special consideration.

Information required.—If advice is desired with reference to dimensions of machines, or arrangement of installations, it will obviously be necessary to furnish full details of the work to be accomplished, accompanied if possible by specimens of the materials to be treated, and information as to the sizes most convenient, or the average fineness desired. Also the kind and amount of power (if any) available, and any other data which may be useful in the preparation of designs and estimates.

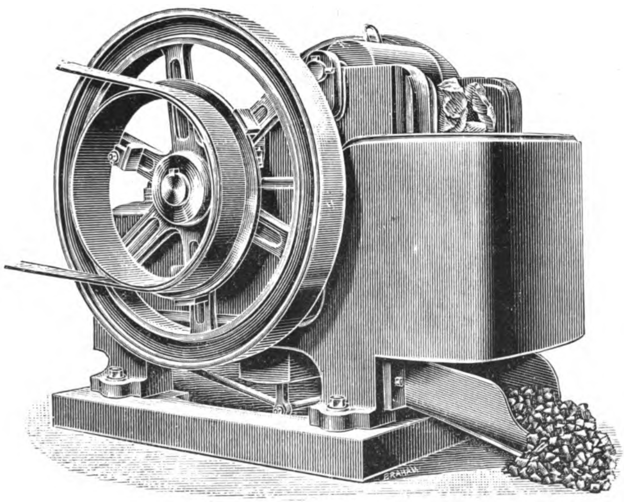


Fig. 5132

STONE BREAKER (Blake improved).—The frame, jaws and working parts are as above described, and the machine is complete with heavy fly wheel, driving pulley, and appliances which can be adjusted for cubing or fine crushing.

The proportions of parts are ample for dealing with the most intractable materials, and the object of a recent improvement is to increase the efficiency of the machine and reduce wear and tear and the repairs incidental thereto.

Approximate power and output.—This necessarily varies with the kind of materials treated, but road metal has been adopted as a convenient basis, the machine being driven at 250 revolutions per minute.

Prices and dimensions.—The following are approximately those of machines in very general use, but they are made of all sizes from 4 by 3 inches in the mouth, to 39 by 12 inches.

PRICES OF STONE BREAKERS, FIG. 5132.

Size of mouth...	inches	10 × 7	12 × 8	13 × 8	16 × 9	20 × 10	24 × 12
Nominal horse power required ...	...	4	4½	4½	6	8	10
Output per hour	tons	4	5	5¼	6¼	9	11
Price of machine	...	£105	£115	£120	£155	£190	£262
Approximate weight	tons	4	4½	4½	7	10	17

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

STONE BREAKERS WITH STEEL FRAMES.—For convenience in transport and handling, the frames are made in steel of suitable size and weight, and sent away in pieces, with the accessories required for putting the machine together on arrival at its destination.

The extra cost of this construction will be found to be insignificant when consideration is given to the immense strength of the machines, and the saving in transport charges which, as is well known in mining experience, not infrequently exceeds the price paid for the machinery itself.

PRICES OF STONE BREAKERS WITH STEEL FRAME.

Size of mouth ...	inches	8 by 6	12 by 6	12 by 8	16 by 8	21 by 9	24 by 12	24 by 16
Nom. H.P. required	...	2	3	4½	5½	8	10	11
Output per hour ...	tons	2	3	5	6	8	11	12½
Price of machine ...	...	£76	£94	£144	£180	£238	£430	£440
Extra for loose pulley	..	£1 10	£1 15	£2	£2 5	£4 10	£4 15	£5
Extra for Screen ...	...	£8	£9	£12	£15	£16	£18	£20
Approximate weight...	tons	1¾	2	3¼	4¼	7	11¼	12½

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

PORTABLE STONE BREAKERS.—Any of the above-named machines can be provided with plain or flanged wheels, with axles and bearings for facility in removal, at an extra cost of £14 to £20.

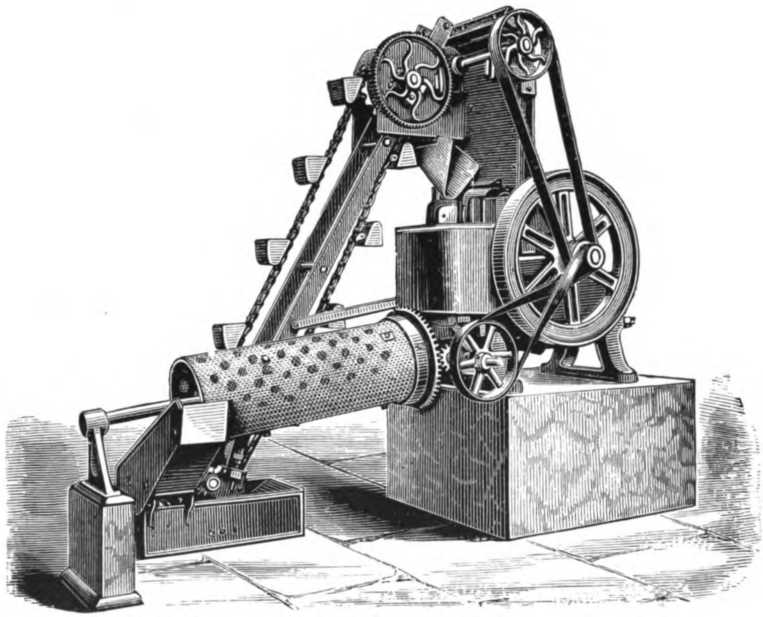


Fig. 5133.

STONE BREAKER WITH SCREEN.—The engraving, Fig. 5133, illustrates an arrangement much used for breaking and automatically screening road metal and materials used in building operations.

The revolving screen is built of steel and driven by gear and belt from the main shaft or the breaker. It will be seen that pieces too large to pass through the perforations are delivered into the hopper below the open end of the screen and, if necessary, are returned to the breaker by an elevator—as illustrated—or by other means.

This, however, is quite inadequate for the close separation or classification in bulk or weight which is essential for many purposes, and such plant must be matter for special treatment.

For power required, output, etc. see the two previous pages.

The following prices are for the breaker with screen and gear for driving it, but not the elevator and appliances connected therewith; the cost of these vary too widely to be tabulated with sufficient accuracy.

PRICES OF STONE BREAKER WITH SCREEN.

Size of mouth ... ... inches	10 by 7	12 by 8	13 by 8	16 by 9	20 by 10
Price with screen	£118	£128	£133	£171	£208

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

STONE BREAKERS FOR ANIMAL POWER, sometimes invaluable for testing rocks, more especially in preparing metalliferous ores for treatment in a Prospector's stamp mill (see page 7 of Section VI. of this series), have cast-iron frame and jaws, etc. and are driven by belt as already described.

PRICES OF STONE BREAKERS FOR ANIMAL POWER.

Size of mouth ... ... inches	6 by 3	8 by 5	12 by 6
Powers required ... ... horse	1	2	3
Output per hour ... ... tons	$\frac{3}{4}$	2	3
Price of machine	£40	£60	£75
Extra for screen	£6 10	£8 10	£9

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

CONVEYORS AND TRANSPORTERS.—Appliances of this kind are illustrated and described elsewhere in these volumes, but it may be well to point out that—with a relatively small capital outlay—ground which may, at first sight, seem hopelessly inconvenient for the work to be performed, can be utilized with great advantage by a suitable installation of bucket conveyors, transporter, overhead tramway, creeper, endless travelling band, etc.

These appliances, judiciously arranged, convey materials at remarkably small cost, almost regardless of distance, level, or direction of traverse, and will frequently save the inconvenience of removal to new premises, as well as effect such economies in time and working expenses, that the cost of plant becomes quite a minor consideration.

QUARRYING AND STONE DRESSING PLANT.—The appliances mentioned in the foregoing pages by no means represent complete equipments of Quarry and Stone yard plant. As already indicated, these vary very widely, as do the character of stone, the quantities to be dealt with, natural facilities for handling, delivery and so forth ; always, of course, designed with a view to economy in working expenses.

But, however greatly the arrangements may differ from each other, some of the under-named plant (in addition to machines such as those mentioned in the preceding pages) will almost invariably be required.

These will probably consist of:

Portable railway and rolling stock of the kinds referred to at pages 91 to 108.

Incline gears for hauling in quarry and on bank.

Pumps for unwatering holes and sumphs.

Winches, chains, blocks, and miscellaneous tools (see pages 118 to 134, etc.)

PLANT FOR PRODUCING ROAD METAL.—The following brief notes relate to a highly successful quarry in which a large portion of the output is converted into road metal, the writer's firm being largely responsible for the arrangement and construction of the plant employed.

Commencing operations many years ago on quite a modest scale, this quarry is now equipped with high-class machinery, including a Collmann engine for driving the stone breakers, screens, electric lighting installation, etc.

The rock drills are of the type Fig. 5137, and the work being in the open (principally in benches) the drills are driven by steam direct and supplied from a boiler provided for each set of drills, so that the length of steam tube is never excessive.

The screens are so arranged that the different sizes of road metal and small stuff are delivered direct into railway wagons or into bin as may be desired, without waste of time and labour in re-handling.

ROCK BORING PLANT.

The two systems referred to in the following pages are the diamond drill, which is invaluable for putting down the deep bores required for exhaustively testing ground for coal, minerals, etc. and the much more familiar percussive drill universally employed in quarry, mining and submarine operations.

The data given with reference to the cost of plant will often suffice for estimating approximate cost, due allowance being made for the variations requisite for difference in strata and local conditions.

ARTESIAN BORINGS.—The extent to which artesian borings have been successfully carried out is by no means generally known, but the following notes relating to what has been accomplished in Queensland alone, may perhaps cause attention to be directed towards similar operations in other countries, and specially in South Africa, where a constant supply of wholesome water is sometimes sorely needed for domestic, pastoral, and agricultural purposes.

ARTESIAN BORINGS IN QUEENSLAND.—Mr. W. Gibbons Cox states that 839 artesian and sub-artesian (or non-flowing) wells had been put down in Queensland up to June 1900, which (excepting 6 per cent. made by the Government) were carried out privately, and free from Government control.

The aggregate number of feet bored for artesian water supply, up to June 1900, was estimated by the Water Supply Department to be 976,711-feet (equal to nearly 185 miles) and this large total is being steadily increased.

Depths of bores.—The average depth is 1188-feet, but there are 59 bores exceeding 3000-feet in depth and ranging up to 5045-feet.

Quantity of water obtained.—The yield from one bore is 6,000,000 gallons per day, from another 4,500,000 gallons, and there are 60 other flows each of more than 1,500,000 gallons per day. The total continuous yield from 515 bores, at which the flow is known or has been estimated, amounted in June 1900 to 321,653,629 gallons per day.

Distribution of water.—The water from many of the bores has channelled its course for more than 40 miles, but systematic channelling by ploughs, now leads the water, in some cases, more than 60 miles, irrigating many thousands of acres of grass land, sugar, and other tropical and sub-tropical products, and permanently filling lagoons, creeks, and low lying places.

Quality of water supplied.—Analyses, fully carried out by the Government analyst, show that with few exceptions the water is in every way fit for domestic consumption, live stock and other purposes.

BORINGS FOR LOCATING MINERALS, often called "Prospecting." The depth of borings in search of gold, iron and other metalliferous deposits is usually less than the average of those for artesian water supply, last referred to, and within the capacity of the machine illustrated by Fig. 5134, which is equal to any depth not exceeding about 2000-feet, but with proper appliances, as will be seen from the following example, much greater depths can be reached.

The experience gained in putting down this Silesian bore seems to confirm the opinion the writer has always held, that the depth of bores is only limited by the capacity of the materials, in boring tools, to withstand the torsional and other strains incidental to the conditions under which the work must be performed.

The following facts indicate that, even with tools of the highest quality, the commencing bore of ample diameter and judiciously reduced as the depth increased, the limit of endurance is reached at a distance of about 6000 to 6500-feet below the machine.

DEEP BORE IN UPPER SILESIA.—This bore, in search of the coal measures, has been carried to a depth of 6571-feet.

Dimensions of bore.—The hole for the first 230-feet is 12-inches diameter and is lined with wrought iron tube about $\frac{3}{8}$-in. thick. At this point and for the next 350-feet the diameter is reduced to $8\frac{1}{4}$-inches and thence is further reduced, step by step, to $2\frac{3}{4}$-inches diameter.

Weight of boring rods.—At a depth of 6560-feet the weight of tubular steel boring rods was 30·155-lbs. (say $13\frac{1}{2}$-tons) and much trouble was caused by rupture of the rods, but work was continued until, finally, at a depth of 6571-feet, 4500-feet of rods fell to the bottom. In attempting to raise these rods, they jammed under a part of the lining tubes and all efforts to raise them proving unavailing, the work had to be abandoned.

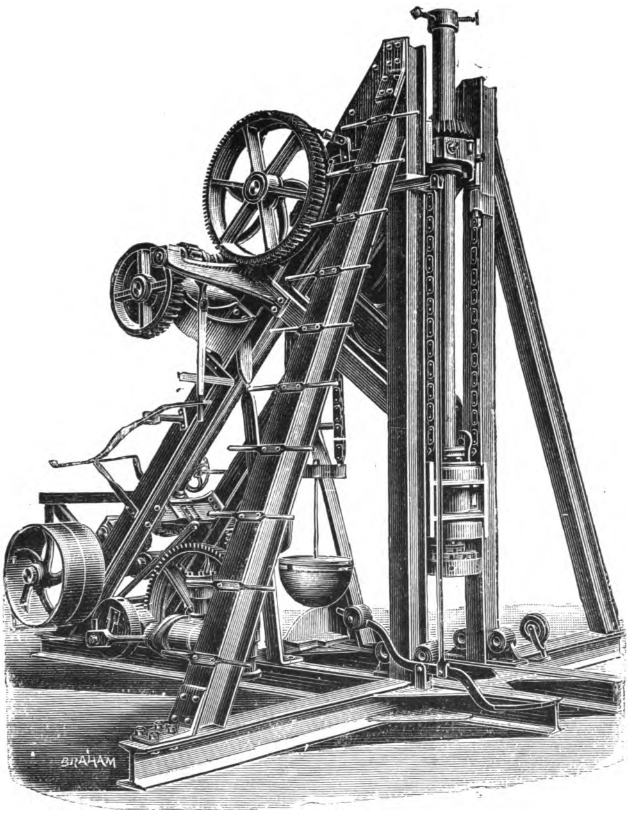


Fig. 5134.

DIAMOND PROSPECTING MACHINE.—The extremely useful invention represented by Fig. 5134, with which the writer's name is associated as patentee, designer and constructor, has been successfully employed, in all parts of the world, in putting down bore holes to any depth (some of them exceeding 4,000-ft.) quickly, and at comparatively small cost, to ascertain the value of the property before investing capital in the slow and very costly process of shaft or well-sinking.

The penetrating power of the diamond drill is obtained by an annular cutting head or "crown" armed with carbonates—often called "Black Diamonds"—the hardest substance known, and rotating it under sufficient pressure; this abrades the rock and leaves a clear space around a central core. The cores are removed from time to time and stored in boxes which—being marked or numbered—form an infallible record of the strata at any point of the depth reached, and are of great assistance in estimating its commercial value, as well as the cost of sinking, or locating the positions for adits, as the case may be.

Construction.—The tripod frame is built of steel and carries all appliances for rotating the drill rods at the speed and with the pressure required for the rock being perforated, and the hydraulic appliances for forcing to the surface the debris (resembling sand) which is abraded by the rotation of the cutting head or "crown"; also gear for raising the rods, as required for removal of the core which has been left inside the bottom boring rod, this being stored for the purposes already referred to.

Boring head or "crown."—The face of a short length of tube is set with carbonates projecting slightly beyond the inner and outer periphery of the tube, the upper end being screwed to connect with the tubular boring rod which is rotated by the machine.

Raising the core.—A clip lowered to the bottom of the bore detaches the core which has been formed inside the boring rod ; this is then lifted to the surface and stored for use when required.

Driving power.—In some cases an engine is coupled to the end of the first motion shaft, but it is usually more convenient and economical to drive by belt from a portable steam engine, an oil engine, or other available motive power.

Efficiency of the machine.—This depends largely on the rods being driven at the speed and with the pressure which, in each case, will give the best results. These have been ascertained by careful and exhaustive experiments carried out by the writer's firm, and provision is made for changes of speed and for maintaining the most suitable pressure whatever may be the weight of rods employed.

Diameter of bore.—This must be in proportion with the depth, and the nature of the strata to be perforated. It may be 2 to 3 inches diameter, or even less for moderate depths in very compact rock, each set of cores weighing only a few pounds, whilst for deep prospecting or artesian well boring, the diameter may commence with 16 inches cores weighing as much as 3 tons, the size of the hole being, however, reduced as it increases in depth.

The extent of variations in sizes of rods, crown and lining tubes is indicated in the following schedule of tools and accessories which are recommended for a machine of the type illustrated, which is capable of boring to any depth up to about 2000 feet, and of which more have been made than of any other capacity.

The price of the machine Fig. 5134, with one pump is £380. If with two pumps, £395.

The price of a portable steam engine of 10 horse power to drive the machine is £265.

DIAMOND DRILL PLANT.—The following is a schedule of articles usually comprised in the equipment of a machine of the type Fig. 5134, to work to a depth of 1000 to 2000 feet :

Two thousand feet of steel boring rod with screwed joints.
Three unset boring crowns, each 2 and 3 in. diameter.
Two ditto ditto 4, 5, and 6 in. diameter.
Two 15 feet lengths of core tube, and four core clips.
Two special connections for boring rods and core tubes.
Two ditto rods to 3 in. tubes.
Seven hundred and fifty feet of steel lining tube 3 in. diameter.
Six hundred and fifty ditto 4 ditto.
Three hundred and fifty ditto 5 ditto.
Ditto ditto ditto 6 ditto.
Diminishing connectors, 6 to 5 in. 5 to 4 in. and 4 to 3 in.
Steel driving shoes 3 in. to 6 in. diameter.
Six flexible hose pipes 1¼ in. diameter.
Three pairs of unions and two water unions.
One chain sheave with spindle and bearings.
One hundred and fifty feet best tested ¾ in. crane chain.
One set of 3 tons pulley blocks.
Two lifting swivels for rods. One set of eccentric clips.
Two pairs tongs for tubes 3, 4, 5, and 6 in. diameter and 4 rod tongs.
A tool box containing a complete set of tools for setting crowns.
Parallel vice 5 in. Set of spanners. Two shifting wrenches.
One gallon oil can and two oil feeders.
Set of spare valves for pumps, and steel pinions.
Ditto gun-metal bearings for main driving shaft, and driving straps.
Two hydraulic lifting jacks of 6 tons power.

The approximate cost of the entire plant, including the prospecting machine, engine and boiler, and the above-named accessories is about £1400

CARBONATES FOR CROWNS vary so much in price, as well as in the number, size and total weight required, that the cost can only be fixed from day to day ; but a useful supply for setting crowns for the above-named machine, and for upholding them can usually be obtained for £200 to £250.

HAND-POWER PROSPECTING MACHINE (not illustrated).—The system of working is similar to that last described, but the machine is designed with light parts affording great facilities for transport and re-erection. A machine to put down bores about 1½ inch diameter and 200-ft. deep costs, complete, about £200.

STANDARD DIAMOND PROSPECTING MACHINES illustrated by Fig. 5135 are similar in principle to those previously described, and combine all the improvements introduced in the most recent practice. They are arranged to be adjusted and fixed at any angle and are capable of boring horizontally, at an angle, or vertically to any depth up to 1000-ft. and of bringing up solid cores showing the exact character of the ground passed through for the entire distance.

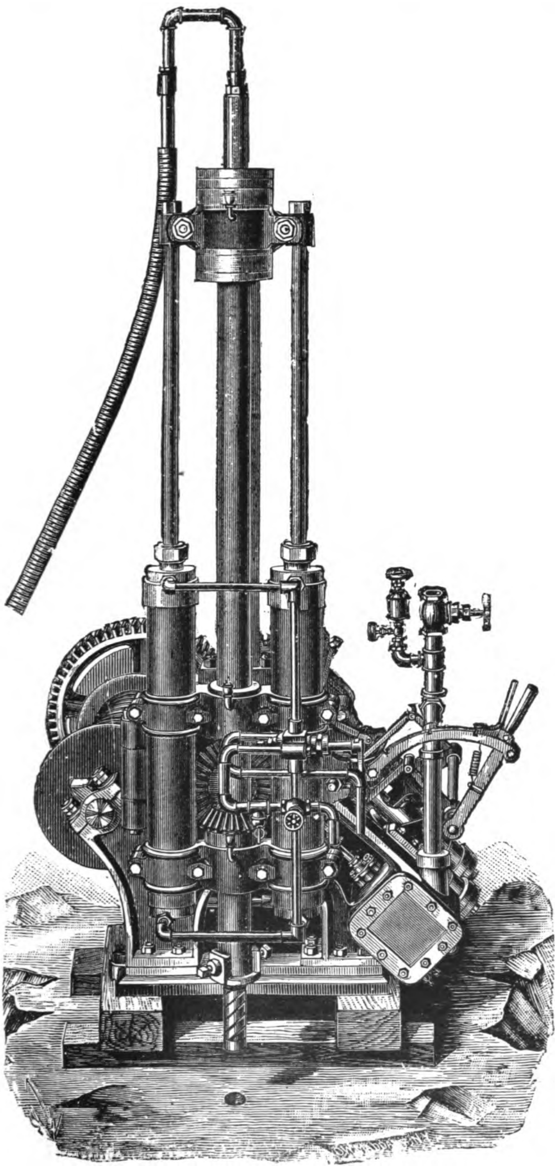


Fig. 5135

Construction.--The machine is complete with its own engines for driving the drill and has a winding gear, also driven by the engines, for lifting the rods to extract the cores, to put in additional lengths, etc., and is complete with all appliances for feeding the drill forward, and for providing the supply of water required to clear the bore hole of debris.

The parts are strongly and simply constructed, and easily handled by an intelligent mechanic. The diamonds (carbonates) forming the cutting surface, are so immeasurably harder than any rock they have to perforate, that the repairs are very small and, with ordinary care, the carbons will not be lost or injured.

The accessories required for proper and efficient working, (other than these mentioned later on), necessarily vary according to circumstances, but for putting down a bore hole, which will not occupy much time, a tripod over the drill, constructed of timber and arranged to carry a lifting block at the top, usually answers every purpose. If however the drill is to remain for a considerable time, (as sometimes is necessary) as for instance, when putting down a deep bore under circumstances which do not admit of the work being carried on without intermission, it may be desirable to erect a more permanent structure.

EQUIPMENT.—This is usually as follows: 200 feet of boring bars, one diamond crown, two blank crowns and a set of diamond setting tools with instructions for using them, a core lifter, a core barrel, safety clamp, hoisting swivel, independent steam pump, hose pipe and coupling, and the tools required for working and maintenance.

The price of the machine complete as described is £795. If with multitubular boiler and feed pump mounted on a wrought iron carriage with road wheels, shafts, etc. the price is £865.

COLUMN PORTABLE DIAMOND DRILL.—Fig. 5136 complete with engines and arrangements for swivelling and fixing the boring bars at any angle. It will be seen that the columns are quite easily fixed vertically or horizontally or in other position desired for sinking shafts or driving headings.

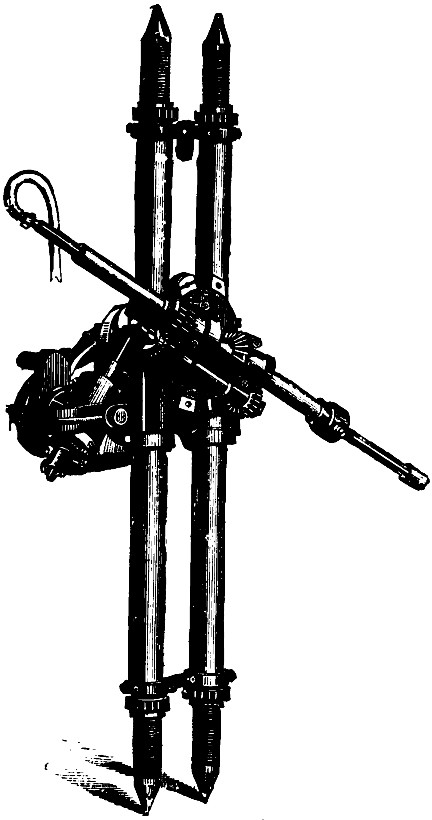


Fig. 5136.

The machine is complete with engines to be worked by steam or by compressed air and the equipment, as follows: 20 feet of boring rods, one crown set with diamonds, two blank crowns ready for setting, one core barrel, core lifter, combination vice, breast drill, a set of twist drills $\frac{1}{16}$ to $\frac{1}{4}$ in., three mechanics' hammers, two oilers, set of steel wrenches, a set of diamond setting tools, bit holder and gauge, six files and 1-lb. of copper wire.

The price of the drill, with outfit specified, is £325.

The cost of packing for shipment and delivery f.o.b. is 5 per cent.

PERCUSSION DRILLS FOR DEEP BORING.—Until the diamond drill was invented and perfected, deep bore holes were almost always put down by percussion drills, differing in details of construction, but all relying on the principle of disintegrating the rock by the falling weight of steel tools of various sections and dimensions.

The appliances used for this system of drilling comprise a strong and rather costly timber headstock or "Derrick," as it is named in the United States of America and in Canada. The height of the headstock is usually from 40 to 50 feet, with a V grooved pulley at the top to carry the rope or chain to which the jumper rods and drills are attached; the other end coils on a drum which is rotated by steam, animal or manual power. The action, therefore, is similar to that of a pile driver, the weight and shape of the tool, and the height and frequency of the drops being regulated by the foreman in charge.

This mode of drilling and the approximate cost of the machinery, are mentioned because cases may arise where the system may be conveniently adopted. As already indicated the "Derrick" is built at the proposed boring. The quantity of timber required for its construction will probably be 8,000 to 10,000 cubic feet and the value of nails, bolts, &c. will be about £25.

Work of this kind is usually done by a contractor who provides his own drilling tackle which costs about £350.

The cost of the engine, boiler, lifting gear, rope or chain headstock pulley, etc. rarely exceeds £225.

NOTES ON PERCUSSIVE ROCK DRILLS.—The chief considerations in the selection of rock drills for quarrying, shaft sinking, tunnelling, ete. are adequate strength of parts, and such simplicity of construction in the drill and its supports that a skilled mechanic is not required to operate the plant; also that it can be easily set up and as easily removed for starting on a new face. Ample experience shows that the drills about to be referred to fulfil these conditions.

Saving in time.—The drills can be worked by either steam or compressed air. If the latter is used the fresh air is turned on to clear the face of fumes after blasting which admits of work being at once resumed, even in the confined space usual in small headings, and it is invaluable in deep mines where hand labour would be almost, if not quite, impossible.

Saving in cost.—In some cases there may be little or no difference in the cost per cubic yard of removing rock by machine, or by hand labour, but the savings in time and in other respects, are frequently of far greater importanee than the direct cost of drilling by hand labour.

A point for consideration in driving long tunnels or headings is the cost of rises for ventilation which are necessary if the work is carried out by hand-power drilling, but not required if drills driven by compressed air are employed. An example of this is furnished by more than 1500-ft. of tunnel having been made by compressed air drills without any rise for ventilation, whereas, if the work had been done by hand, the cost of the ventilating shafts would have more than equalled the cost of the tunnel as driven.

ELECTRIC ROCK DRILLS.—The ease with which electric power is transmitted is a strong inducement to apply it to rock drills ; much time and money has been expended in producing these machines, but the results obtained do not seem, hitherto, to have been commercially successful and for this reason the existing appliances are not illustrated or described.

SUB-AQUEOUS DRILLING is referred to at pages 169 and 170.

COST OF PERCUSSIVE DRILL PLANT.—Before proceeding to describe the component parts, it may be well to give some data with reference to the cost of small installations for working respectively by compressed air, and by steam direct. The cost of large plants is usually estimated by the Engineer in charge.

SIX-DRILL COMPRESSED AIR PLANT for tunnels, mines, &c.—A useful plant for these purposes consists of an engine and air compressor, with expansion valve, mounted on one bed plate, an air receiver of about 280 cubic feet capacity, with all necessary fittings including safety valve, pressure gauge and pipe connections with the compressor. The 6 rock drills are 3¼ inch diameter, with stretcher bar or column for each, with clamp suitable for level driving or shaft sinking, 6 lengths, each 50 feet, of flexible tube with brass screw couplings, 6 sets of steel drills, 120 in all, of various lengths and a set of smith's tools for sharpening the drills.

The price of this plant is about £940

If a steam boiler (not included in the estimate) is required, it should be of 20 horse power, and costs with fitting, about £200

TWO-DRILL COMPRESSED AIR PLANT.—The air compressor, with fly wheel and fast and loose pulley, is carried on a bed plate arranged to afford facilities for transport, and fixed on an air receiver of about 56 cubic feet capacity, with fittings and pipe connections to the compressor, two 3¼ in. rock drills, each with stretcher bar and clamp, two lengths, each 50 feet, of flexible tube with brass couplings, two sets of steel drills, 40 in all, and a set of smith's tools for dressing them.

The price of this plant is about £370

The cost of engine and boiler of suitable power is ... .. £190 to £265

ONE-DRILL COMPRESSED AIR PLANT with belt-driven air compressor, air receiver and the necessary outfit of tools and accessories, costs about £245

Engine and boiler of suitable power costs about £125

TWO-DRILL STEAM PLANT FOR OPEN BLASTING.—This comprises two 3¼-in. rock drills to work by steam, two tripod carriages with appliances for fixing the drills to work horizontally, vertically, or at any angle, complete with weights and accessories, vertical cross-tube steam boiler with fittings, two lengths, each 50-ft. of flexible steam hose with brass screw couplings, two sets of steel drills (40 in all) of various lengths, and blacksmiths' tools for dressing the drills costs about £280

ONE-DRILL STEAM PLANT with steam boiler and proportionate quantities of tools and accessories, as last described, costs about £155

The cost of packing for shipment and delivery f.o.b. for any of these plants is usually about 5 per cent.

PERCUSSIVE ROCK DRILLS.—The Marston drill, represented by Fig. 5137 is adapted to work by steam or compressed air and has gained a good reputation for durability, even when drilling very refractory rock, and for low cost of maintenance. The drill is attached by a universal clamp to a tripod, as shown, to a stretcher bar, or to a multiple drill carriage as may be required and is available for putting down holes in any position, in quarrying, driving headings, shaft sinking, &c.

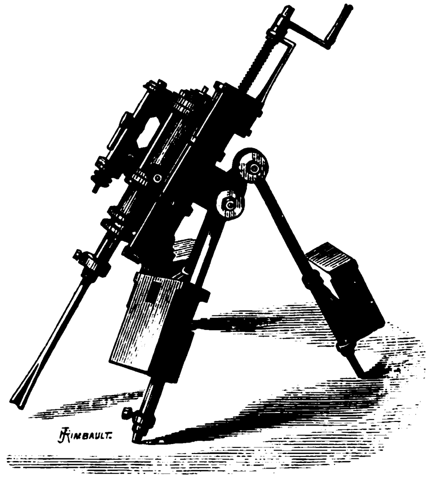


Fig. 5137.

The two larger sizes are found to give the best results in heading or tunnel driving because, as is well known by experts—time of working and charges of explosives being equal—a relatively larger quantity of rock is brought down when the holes are large, than when they are small

A certain length of flexible hose is required for each drill to give sufficient range of work without removing or laying fresh mains during working hours, but wrought iron pipes cost less and are far more durable for that purpose than the best flexible hose, so that the length of the latter, for each drill, rarely needs to be more than about 50-ft.

PRICES OF ROCK DRILLS, FIG. 5137.

Diameter of cylinder... ... ... inches	2½	3	3½	4
Price of drill	£40	£47	£53	£60
Ditto tripod with weights	£6	£6	£7	£8
Ditto stretcher bar and clamp	£9	£9	£10	£10
Ditto set of 20 steel drills	£7	£8	£9	£10
Ditto flexible hose per foot	3/-	3/-	3/-	4/-
Ditto set of gun metal unions	14/-	15/-	16/-	20/-

The cost of packing for shipment and delivery f.o.b. is 5 per cent.

HAND POWER PERCUSSIVE DRILL (not illustrated).—The drill can be carried on a stretcher or on a tripod and adjusted to any angle for use in heading, shaft or open quarrying ; it can also be fixed on an independent standard for holeing in stone yard.

The advantages claimed for this drill are that it rotates and feeds automatically and operated by one man turning a handle, will make true round holes at quite twice the speed attainable by jumping in the ordinary manner ; also that the force of the blow can be quickly varied between 60-lbs. and 200-lbs.

The price of drill with telescope stretcher bar is £25

If mounted on a tripod, the price is about... ... ... £27

A set of 17 drills required for each maching costs about £3

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

AIR COMPRESSORS, RECEIVERS, and their accessories, vary so much in dimensions and design that reference can only be made to those which are in general use in connection with rock drilling plant of moderate proportions, such as those specified. Estimates for compressing plant of larger dimensions for drilling, tunnelling by the shield system, sinking caissons, or any other purpose, cannot be prepared without details of the conditions to be fulfilled.

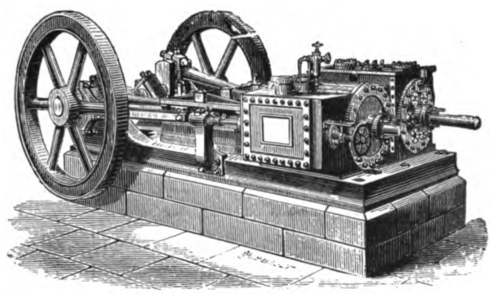


Fig. 5138.

FIXED AIR COMPRESSOR AND ENGINE, Fig. 5138.—The steam and air cylinders are fixed side by side at one end of a massive bed plate, the valve chests for both steam cylinders and air compressor being perfectly accessible for examination, without interference with the rest of the engine. The crank shaft is provided with two fly wheels, as shown ; the cranks are set to give the highest useful effect and, in design and construction, this object has been kept steadily in view.

If engines, with the air compressor fixed tandem behind the steam cylinder are preferred, the prices do not differ much from those given below.

The boilers are of the locomotive type and are complete with chimney and all fittings, including steam and exhaust connections for a moderate distance—say about 20-feet—between engine and boiler.

PRICES OF AIR COMPRESSORS, Fig. 5138.

Diameter of air cylinder inches	10	12	14	16	18	20
Do. steam do. ,,	10	12	14	16	18	20
Length of stroke ... ,,	16	16	24	24	30	30
Price of compressor ...	£230	£280	£355	£415	£560	£615
Patent expansion valve, extra	£20	£22	£25	£30	£35	£37
Loco. boiler and connections	£125	£145	£198	£236	£297	£317
Wheels, forecarriage, &c., extra	£17	£24	£25	£30	£35	£35

The cost of packing for shipment and delivery f.o.b. is 5 per cent.

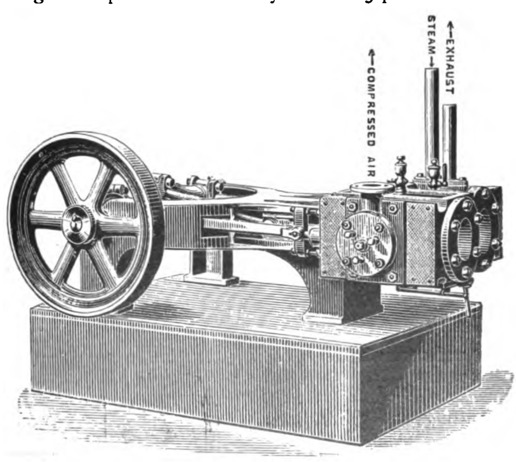


Fig. 5139.

SMALL AIR COMPRESSOR and ENGINE, Fig. 5139, is intended to supply compressed air for a small number of drills. The smallest size drives one drill ; the second, two small drills ; and the largest size two 4-in. drills.

It is almost invariably desirable to have a vertical cross-tube boiler for the special service of the drills used for quarry work, open cutting, etc. These boilers are of the type indicated in Fig. 5125, and referred to in detail in Section I. of this series.

PRICES OF AIR COMPRESSORS, FIG. 5139.

Diameter of air cylinder ... ... inches	$6\frac{1}{4}$	$8\frac{1}{2}$	10
,, steam cylinder ... ... ,,	$7\frac{1}{2}$	10	12
Price of compressor	£70	£90	£115
,, vertical boiler, type Fig. 1049 Section I. ..	£50	£60	£74

CYLINDRICAL AIR RECEIVERS.—To insure a steady supply of compressed air to the drills, a receiver of ample capacity is fixed in any convenient position relatively with the drills, by preference, near to the compressor.

The shell of the receiver is made of mild steel plates machine rivetted and tested to a pressure of 150 lbs. per square inch. The fittings consist of inlet and air supply pipes, blow off cock, safety valve and dial pressure gauge.

The under-named are useful sizes, but receivers of any other dimensions or construction are made, as may be required.

PRICES OF CYLINDRICAL AIR RECEIVERS.

Length of receiver ... feet	8	10	12	15	20	20
Diameter ,, ... feet	3	$3\frac{1}{2}$	4	5	5	$5\frac{1}{2}$
Price ,, ...	£33	£42	£55	£70	£98	£118
Contents ... ... cub. feet	56	95	144	285	392	460
Approximate measurement ,,	80	115	180	332	445	525

The cost of packing for shipment and delivery f.o.b. is 5 per cent.

PORTABLE DIRECT ACTING COMPRESSORS.—The steam cylinder and the air compressing cylinder are fixed on a cylindrical air receiver ; the compressor piston is worked by a rod connected with the steam piston, and the crank shaft carries two fly wheels to insure steady running.

The receiver is constructed of mild steel plates and is tested by hydraulic pressure to 150 lbs. per square inch. The fittings consist of inlet and outlet valve, blow off cock fixed at the lowest part of the receiver, pressure gauge and safety valve.

If mounted on travelling wheels and provided with shafts (the cost of which is given in the list of usual sizes and prices) the compressor is easily transported to any place where its services are required.

PRICES OF PORTABLE AIR COMPRESSORS.

Diameter of air cylinder ... ... inches	8	10	12
,, steam cylinder ... ... ,,	8	10	12
Length of stroke ... ... ,,	12	14	14
Price of compressor and receiver	£135	£185	£220
Approximate measurement ... ... cubic feet	150	220	270
Extra for road wheels and shafts	£30	£33	£35
Locomotive boiler, fittings and connections	£95	£125	£147

The cost of packing for shipment and delivery f.o.b. is 5 per cent.

VERTICAL AIR COMPRESSORS.—A neat and highly efficient arrangement (not illustrated) was originally designed to supply air at a pressure suitable for working pneumatic hoists (referred to at pages 83 and 84), drilling and other machine tools, but is equally adapted for use in connection with coal cutting machines, rock drills, etc.

It is sometimes a great advantage for the compressor to occupy only small ground space, and to be easily moved. These conditions are fulfilled by the vertical compressor, and being self-contained on its own base plate, little or no foundation is required. It is provided with appliances for complete lubrication, and all parts are accessible for examination.

WELL BORING TOOLS.

BORING TOOLS for testing ground for minerals, foundations, water, &c., have been designed to suit the varied conditions under which they have to work ; those in general use are illustrated on the annexed page (Fig. 5140), and consist of :—

1.—Well rod, usual length 10 ft.
2.—Worm auger.
3.—Open auger, for clay.
4.—Flat chisel, for stone or flint.
5.—Spring dart, to draw faulty pipes from the bore hole.
6.— Ditto ditto, for smaller pipes.
7.—Bell screw, for withdrawing broken rods.
8.—Bell box, for ditto
9.—Auger nose shell, with valve for loose soil or sand.
10.—Flat nose shell, for similar purposes.
11.—Shoe nose shell, for harder ground.
12.—Hand dog, for screwing and unscrewing the rods.
13.—Pipe clams, or rests.
14.—T-Chisel, for flint or stone.
15.—Wad hook, for withdrawing stones, &c., which may fall into the draw hole.
16.—Spiral augular worm for withdrawing broken rods.
17.—Diamond or drill-pointed chisel, for hard ground.
18.—Lifting dog, for raising and lowering the rods.
19.—Long pipe clams or rests.
20.—Tillers or levers for turning the rods.
21.—Wrought iron screwed well bore pipe.
22.—Short rod, with swivel head.
23.—Crow's foot for extracting the broken rods from bore hole.
24.—Pair of well rod joints ready to shut up for greater lengths.
25.—Pipe tongs or heaters for making joints in pipes.
26.—T-piece or pipe dog for lowering the pipes.
27.—Brazed and collared pipe, with water-tight soldered joints.
28.—Common rivetted pipe, strong make.
29.—Spring hook to be attached to well rope for raising tools, &c.
30.—Windlass complete, for boring or sinking.
31.—Strong well sinking bucket.

The following estimates will suffice to establish the cost, with sufficient accuracy, for an epuipment of tools for almost any depth or formation.

BORING PLANT FOR THIRTY FEET DEPTH consists of five 5ft. lengths of boring rods and one swivel rod, one 2-in. clay auger, one 2in. shell nose auger with valve, one 2in. flat chisel, one 2in. worm auger, one spring hook, one pair of tillers, one lifting dog and two hand dogs or wrenches. The price of this set of tools is £12 10 0.

BORING PLANT FOR FIFTY FEET DEPTH consists of ten 5ft. lengths of boring rod and one swivel rod, one clay auger each 3¼ and 2½in., one shoe nose shell with valve each 3 and 2in., one flat chisel each 3¼ and 2½in., one T chisel each 3¼ and 2½in., one worm auger, one spring hook and 30ft. of rope, one pair of tillers, two lifting dogs, two hand dogs, one rigger and carriage. The price of this set of tools is £28.

Extra length of boring rod, per 5ft. length is 18/6.

BORING PLANT FOR ONE HUNDRED FEET DEPTH consists of ten 10-ft lengths of boring rod and one swivel rod, one clay auger each 4¼ and 3¼ in., one shoe nose shell with valve each 4 and 3 in., one auger nose shell each 4 and 3 in., one flat chisel each 4¼ and 3¼ in., one T chisel each 4¼ and 3¼ in , one worm auger, one spring hook and 30 ft. of rope, one pair of tillers, two lifting dogs, two hand dogs, one bell box, one rigger and carriage, one auger board and one auger clearer. The price of this set of tools is £40.

Extra length of boring rods, per 10 ft. length, £1 1 0.

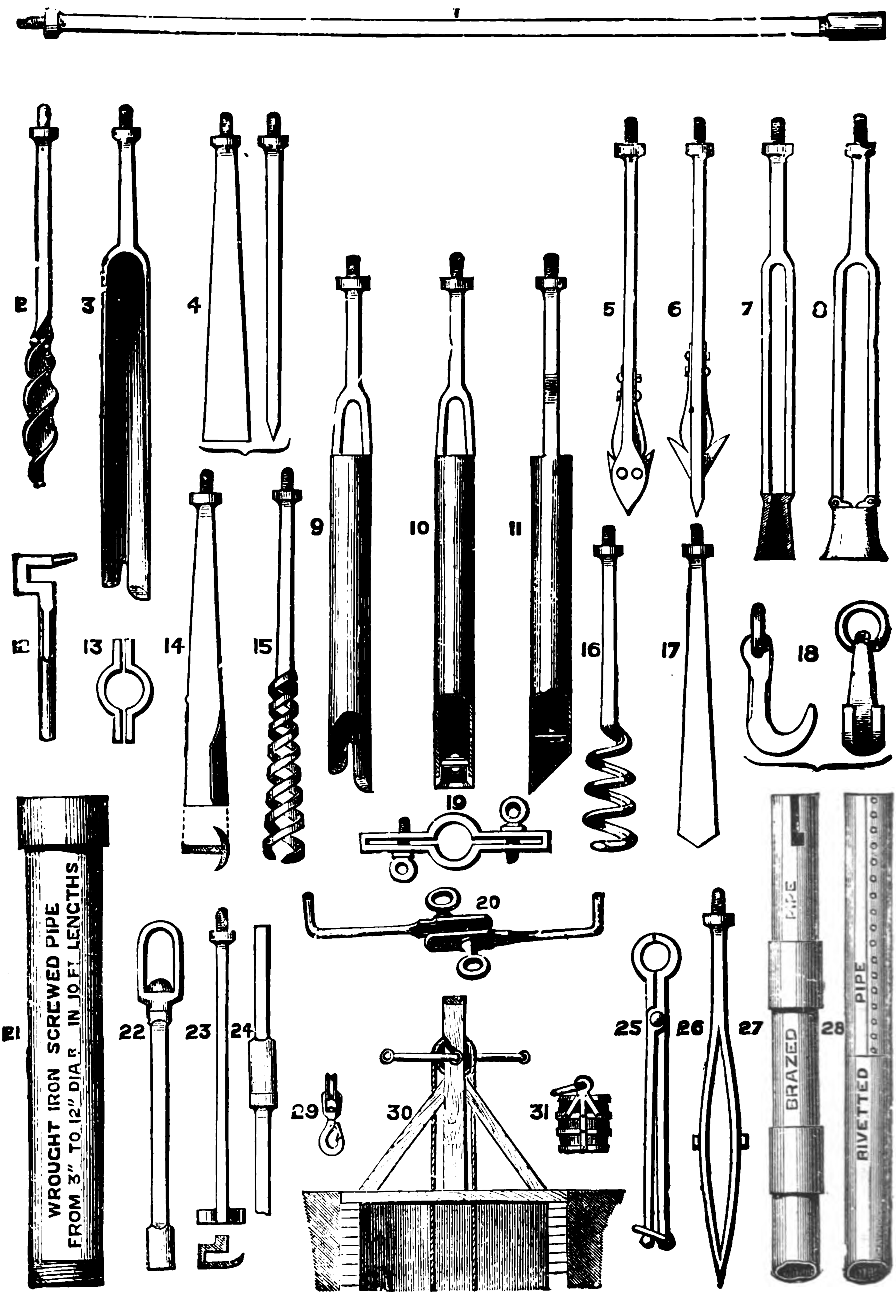

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
WROUGHT IRON SCREWED PIPE
FROM 3" TO 12" DIA.R IN 10 FT LENGTHS
22
23
24
25
26
27
28
BRAZED PIPE
RIVETTED PIPE
29
30
31

Fig. 5140.

BORING PLANT FOR TWO HUNDRED FEET DEPTH consists of twenty 10 ft. lengths of boring rod and one swivel rod, one clay auger each 5¼- 4¼ and 3¼ in., one shoe nose shell with valve each 5, 4 and 3 in., one auger nose shell each 5, 4 and 3 in., one flat chisel each 5¼, 4¼ and 3¼ in., one T chisel each 5¼, 4¼ and 3¼ in., one worm auger, one spring hook with 30 ft. of rope, one pair of tillers, two lifting dogs, two hand dogs, one bell box, one rigger and carriage, one auger board, and one auger cleaner.

The price of these tools is £64.

Extra length of boring rods, per 10 ft. length, 1 4 0.

BORING PLANT FOR THREE HUNDRED FEET DEPTH consists of thirty 10 ft. lengths of boring rod and one swivel rod, one clay auger each 6¼, 5¼ and 4¼ in., one shoe nose shell with valve each 6, 5 and 4 in., one auger nose shell each 6, 5 and 4 in., one flat chisel each 6¼, 5¼ and 4¼ in., one T chisel each 6¼, 5¼ and 4¼ in., one S chisel each 6¼, 5¼ and 4¼ in. one worm auger, one crows foot, one bell box, one spiral worm, one spring hook with 30 ft. of rope, one snatch block, one pair of tillers, two lifting dogs. two hand dogs, one bell box, two rod rests, one rigger and carriage, one auger board and one auger cleaner.

The price of these tools is £96.

Extra length of boring rod, per 10 ft. length, £1 4 0.

BORING PLANT FOR FIVE HUNDRED FEET DEPTH consists of fifty 10 ft. lengths of boring rod and one swivel rod, one clay auger each 8¼, 7¼, 6¼ and 5¼ in., one flat chisel, one T chisel and one S chisel each 8¼, 7¼, 6¼ and 5¼ in., one shoe nose shell with valve and one auger nose shell each 7, 6, 5 and 4 in., two worm augers, two bell boxes, one crows foot, one bell screw, two pairs of tillers with spare screws, two lifting dogs, four hand dogs, two rod rests, one spring hook with 30 ft. of rope and snatch block, one rigger and carriage, one auger board and cleaner.

	£	s.	d.
The price of the tools is	178	0	0
Extra length of boring rod, per 10 feet length	1	12	0
Boring plant for 1000 ft. depth costs about	440	0	0
Extra length of boring rod, per 10 ft. length	2	4	0
Ironwork for shear legs	3	0	0
Sinkers Windlass for wells up to 200 ft. depth	12	0	0
,, ,, ,, 300 ,, ...	24	0	0
,, ,, ,, 1000 ,, ...	38	0	0

Lining tubes for bore holes are usually made with swelled or flush screwed ends.

PRICES OF LINING TUBES FOR BORE HOLES.

External diameter ... inches	3	3½	4	4½	5	6	8	10	12
Brazed and collared pipes, per ft.	2/7	2/10	3/-	3/2	3/4	4/4	6/-	8/-	11/-
Swelled and screwed end ,,	1/6	1/9	2/-	2/-	2/3	2/9	3/9	...	...
Flush screw end ... ,,	2/4	2/8	3/3	3/9	4/6	5/8	9/4	13/6	23/-
Steel driving collars and shoes	13/-	16/6	20/6	25/-	30/-	38/6	50/-	75/-	120/-

The cost of packing for shipment and delivery f.o.b. is 5 per cent.

TUBE WELL PUMPS consist of a pump head fitted with steel-pointed perforated driving tube, and wrought iron rising main for a total lift of 15 feet. The prices of drive tube for greater depth are given below.

For prices of steam and other driving gears for pumps see Section III., pages 19 to 37.

PRICES OF TUBE WELL PUMPS.

Diameter of drive tube, inches	1¼	1½	2	3	4
Approx. capacity, galls. per hour	150 to 500	200 to 700	300 to 1000	500 to 2000	1000 to 4000
Price of tube, with drive point, for 15 feet lift	£1 10	£2	£2 10	£5	£6
Price of pump head	£2 10	£3	£3 10	£5	£6
Extra drive pipe, per foot ...	1/3	1/7	2/6	4/-	5/-

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

TUBE DRIVING APPARATUS for shallow wells costs about £4 to £5.

If with tripod, winch, block, etc. the cost ranges from £15 to £20.

SCREW PILE STRUCTURES.

Although screw pile foundations—invented by the late Mr. Alexander Mitchell and subsequently improved by the late Mr. George Wells—came into use about 50 or 60 years ago (1840 to 1850), the inventors are already all but forgotten, and the object in briefly mentioning them is to associate their names with this extremely useful and economical system of construction with which the writer's firm has, in recent years, been identified.

The auger point and serrated screw, introduced by Mr. Wells, has enabled piles to be put down, quite easily, in ground which would have presented great difficulties if the form adopted by Mr. Mitchell had been adhered to.

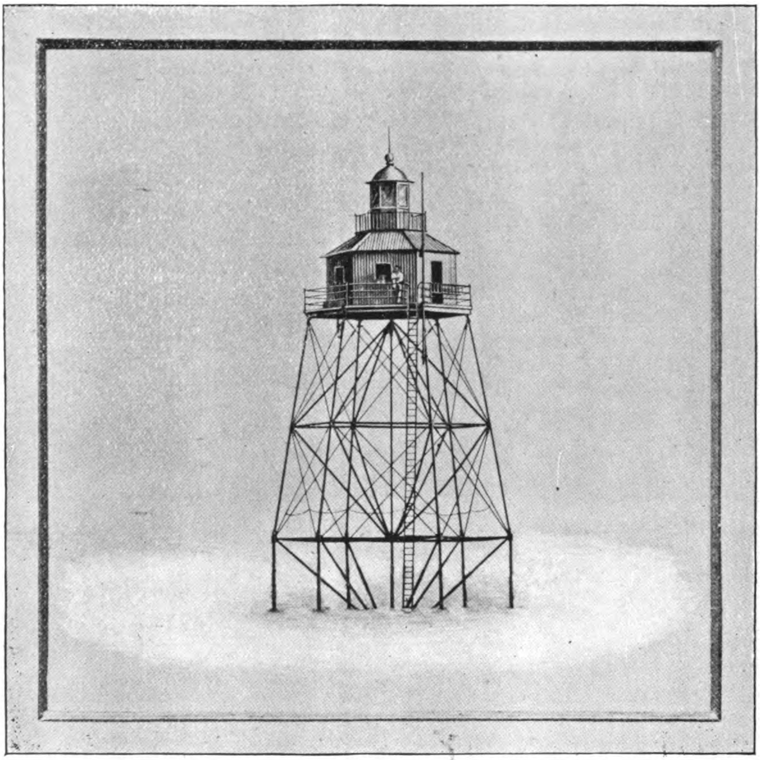


Fig. 5141.

Screw pile structures, such as lighthouses, breakwaters, piers, jetties, bridge piers, foundations for buildings, etc. are erected at far less cost than would be incurred if they were built in concrete or masonry, and are completed in very much less time.

Breakwaters.—An early example of the advantage of screw piles was furnished in the formation of the Portland breakwater, where a staging of timber piles was constructed, the lower ends being shod with cast-iron screws, and screwed into the ground. These piles having been left in and surrounded by rubble hearting, are a source of great strength.

Wrought iron or steel piles, used in a similar manner, not only serve for staying purposes, but also act as ties to bind the mass, and prevent the washing away which is so detrimental to the whole strength of structures which depend upon the size and weight of the blocks employed.

LIGHTHOUSES.—The first lighthouse erected where screw piles where adopted was at Fleetwood-on-the-Wyre in 1839; this was followed by many others around the coasts of the United Kingdom (Maplin Sand, Belfast Lough, Cork Harbour, etc. etc.), and abroad, in the Mediterranean, Indian Ocean, on the coasts of America, in Australia, and so forth. Fig. 5141 represents a lighthouse on the Italian coast.

The Cape Jaffa lighthouse, erected on the most exposed reef on the S.E. coast of Australia, and the Tipparu Reef lighthouse are considered to be the finest structures of the kind, in the world.

Accommodation for Attendants.—There are 11 rooms in each of the lighthouses; seven of these are living rooms (one being nearly 17-ft. square), which are occupied by the wives and families of the attendants, the good promenades enabling them to take much more exercise than can be obtained in stone lighthouses.

STRUCTURAL ADVANTAGES.—Screw piles lend themselves peculiarly to lighthouse construction for the following reasons:—

They can be erected in positions where it is impossible to place any other permanent structure.

The area exposed to the action of sea and wind is quite insignificant.

The vibration is extremely small, this is largely due to the efficient manner in which the structure is braced, and is an important feature when a delicate apparatus like a lantern is involved.

Maximum space, comfort and convenience, as already mentioned, can be provided for attendants.

They can be more easily approached than stone lighthouses in rough weather.

The original surface of the ground is not disturbed, and no increase in scour is created to deteriorate foundations.

Materials employed.—The action of sea water is much less rapid on best forged scrap iron, than on rolled iron or steel bars, especially if there is much sea-weed and, in many cases, the former only should be used from the surface of the bed (sand, mud, clay or rock) to about 10-ft. above high water.

Cast iron is not recommended, because it is liable to rather rapid deterioration, especially in hot climates, and to be broken by floating masses of wreckage. Cast-iron piles also offer a much larger area of resistance to wave action.

The screws may be of cast iron or cast steel, the latter being now frequently used. If foundation piles have to be put down in rock—other than chalk—it is necessary to form holes for the insertion of the screw, and where the surface is exposed at low water, the pile should be cemented in with Portland cement, not to increase the strength of the structure, but to prevent oxidation of the iron, Portland cement being the best preventive of this, between wind and water.

Information required, see "Designs and estimates," page 200.

PIERS AND JETTIES.—For promenade piers, and for some commercial piers and jetties, screw piles are the most convenient and—if the life and cost of maintenance of a timber structure be taken into account—the metallic construction is certainly the most economical.

WROUGHT AND CAST-IRON PILES.—Solid wrought-iron piles withstand the action of waves and shingle far better than hollow cast-iron piles. The capital outlay for the former is larger, but the life is longer and there is much less liability to damage in heavy weather, blows from wreckage, etc.

The latter casualty often occurs around the British coast where, however, cast iron has been very largely used in the construction of promenade piers, partly no doubt on account of cheapness.

Although the large diameter of hollow cast iron piles gives them a stronger appearance they are, in reality, infinitely weaker by reason of the lack of uniformity in thickness of metal, and of the quality of cast iron used, it being far too commonly held that anything is good enough for pier piles.

BRACING.—The usual practice of attaching the bracing to cast-iron lugs by one bolt to one brace and two ties, is evidently to be deprecated, because the failure of one bolt or lug causes the collapse of two tiers of braces. This element of weakness is, however, easily avoided by providing wrought iron straps with a separate bolt for each brace and tie connection.

SIZES OF PILES.—The dimensions of piles, whether in wrought or cast iron, and of screws, are varied indefinitely to suit the character of the structure and the purpose for which it is to be used. The nature of the foundations (sand, mud, clay or rock) must also be taken into consideration when determining the dimensions of both piles and screws.

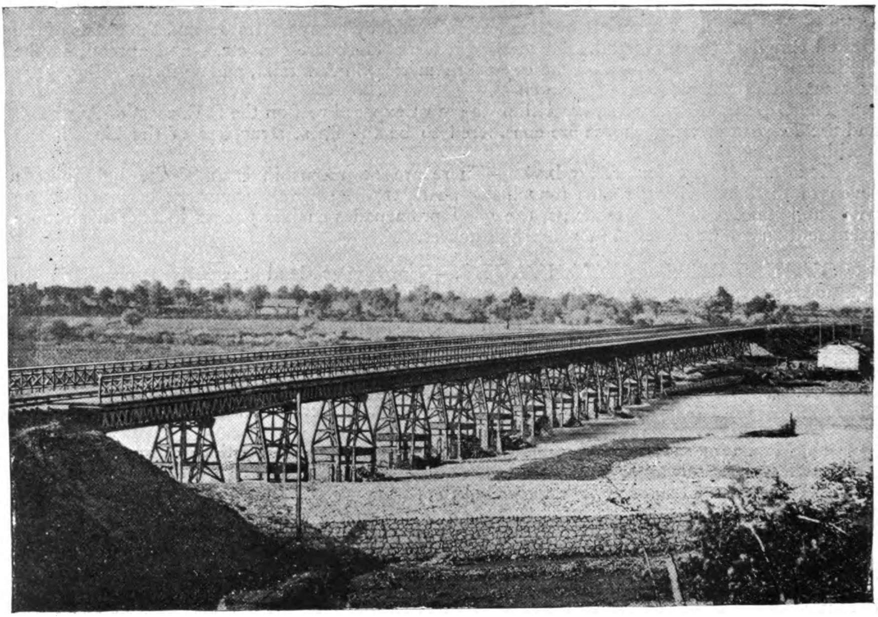


Fig. 5142.

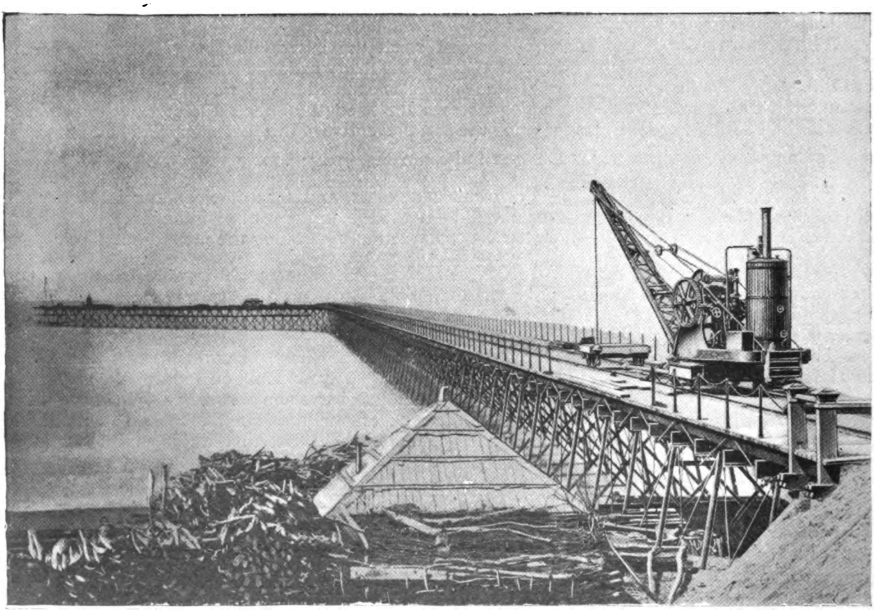


Fig. 5143.

LIFE OF SCREW PILE STRUCTURES.—The limit has not yet been reached, but wrought-iron screw pile piers and jetties which have been in constant use for more than 55 years, are perfectly sound and seem likely to remain so for an indefinite period.

As regards cast iron, however, we have ample evidence of rapid wear by abrasion on a shingly beach, and of the measures which have to be resorted to for the protection and maintenance of both piers and jetties.

SUMMARY.—The advantages claimed for wrought iron screw pile structures are, that they can be erected more rapidly than any other type, also that they are elegant in appearance when completed, and are easily and cheaply upheld.

COMMERCIAL JETTIES, BRIDGE PIERS. &c.—For the accommodation of ocean going steamers of great size and draught, as well as for piers for bridges of large span, it is difficult to conceive anything more satisfactory than the well-known cast iron cylinders which are sunk to the depth required by one or other of the methods (pneumatic caisson, grab dredging, etc.) mentioned elsewhere in this volume, and afterwards filled with cement concrete.

The facility which this method of construction offers for increase in width or length is, sometimes, a matter of no small importance.

WROUGHT IRON SCREW PILE PIERS FOR BRIDGES.—It is claimed for these that: (1) They can be erected in about one fourth the time required for masonry or steel structures. (2) They present no appreciable resistance to flow of water and (3) no abutments are required.

These advantages were recognised in the construction of the Poti and Tiflis (Caucasus) Railway, where these piles were adopted for all the bridge piers, the Rion bridge, Fig. 5142 being one of them, as well as for the large landing pier at Poti on the Black Sea, see Fig. 5143.

These bridges and the pier were erected in the year 1869 and 1873 and are now in excellent condition.

DESIGNS AND ESTIMATES FOR SCREW PILE STRUCTURES.—It will be evident from the foregoing remarks that full information is required with reference to dimensions, foundations, etc. as well as details of the ordinary and exceptional conditions which the intended structure will have to withstand.

If materials only are required, this should be stated, but if it is desired to enter into a contract to include design, erection and completion, the clearest possible details should be given relating to all circumstances which affect the design of the structure, the cost of the work, and the time required for its completion.

FORM OF SCREW.—Experience in designing and erecting screw pile structures shows, that attention to certain details in the form of screw (which do not admit of written explanation) make a great difference in the time and cost of putting down screw piles. The essence of them, however, is that the screw shall enter freely and not tend to "pack" the sand or other strata, or carry down large pebbles which may be a source of considerable inconvenience.

PRICES OF SCREW PILES.—The fluctuations in cost of materials are so great that reliable estimates can only be made from day to day, but the following figures will afford some indication of the probable cost of the principal materials, delivered alongside export vessels in British port.

WROUGHT IRON SCREW PILES.—The piles are, of course, made in lengths to suit the conditions to be fulfilled. The bottom pile, fitted with a Well's serrated edge auger pointed screw, is assumed to be 20-ft. long, that being often a convenient length.

The upper piles are connected by forged iron or steel cylindrical couplings and the probable cost of these is given separately so that approximate estimates may be made of the lengths which may be required.

PRICES OF WROUGHT-IRON SCREW PILES.

Diameter of pile ... ... inches	4½	5	6	7
Length of bottom pile ... ... feet	20	20	20	20
Price of bottom pile with screw, about... ...	£7 15	£11	£14 10	£20
,, upper lengths, per foot ,, ...	5/6	6/9	9/6	12/6
,, couplings, each ,, ...	33/-	38/6	50/	66/-

CAST IRON SCREW PILES.—The cost per foot of hollow cast-iron screw piles depends on the market prices and thickness of metal, but the under-named generally suitable dimensions may, perhaps, serve as a basis for estimating the approximate cost.

The piles are assumed to be made in lengths of 9 to 12-ft. with faced ends and connected by cylindrical couplings.

PRICES OF HOLLOW CAST-IRON SCREW PILES.

Diameter of Pile ... ... inches	10	12	15	18
Thickness of metal ... ... ,,	$\frac{7}{8}$	1	1	1
Price of pile ... ... per foot	8/9	12/-	15/-	18/-

SUPPORTING POWER OF SCREW PILES.—In compact sand, screw piles carry a total load corresponding to seven or eight tons per square foot of area of screw.

PILE SCREWING PLANT consists principally of the screwing head which is attached to the top of the pile, and appliances for rotating it until the point and blade of the screw become firmly embedded in the ground.

Screwing head.—This is built of steel plates with wrought iron or cast steel centre piece, and the appliances for securing it to the pile. The rim is arranged to take a turn of rope and is provided with pockets for hand capstans, chain swifters, etc. etc.

Rapid and uninterrupted progress in erection depends largely on the perfection, of this simple (and apparently not very important) portion of the plant.

Steam power screwing gear.—Several arrangements have been employed, but a powerful double cylinder steam winch with link reversing motions and double purchase gear is usually the most convenient. There are two winding drums and warping capstans fixed at each end of each drum shaft, for use as hereafter described. The winch is usually 30 to 40-ft. behind the pile being screwed and may be mounted on an under-carriage with wheels, or on a low trolley, to follow the work without lifting and re-fixing, provision being made for readily lashing the winch or carriage to a beam, or other fixed object, when screwing in very hard ground.

Screwing rope.—This should be made of best Manilla hemp, slightly tarred, 6 to 8 inches circumference, according to the size of screw and nature of ground, and firmly spliced to form an endless rope.

Mode of working.—The endless rope is passed around the rim of the screwing head and another part of it is coiled on one of the winch capstans. The bight is held by one man near the winch, another man feeding the rope on the rim of the screwing head and so (the winch being in motion) the pile is put down.

A fixed length of rope is sometimes used when only a few piles are to be put down, but an endless rope and suitable screwing plant save quite 50 per cent. in the cost of erection.

Position of winch—As already mentioned the winch should be 30 to 40-ft. away from the pile, and should be so arranged that it does not matter what is the height or angle of the screwing rope relatively with the capstan.

Cost of plant.—This necessarily varies considerably, but for average work it will usually be obtainable at about the following prices :—

Powerful steam winch as described £80

If with boiler, injector and usual fittings and connections £165

The price of screwing head with keys and capstan bars, vary in cost from ...£35 to £75

SUBSIDIARY ERECTING PLANT.—A steam or electric crane for handling the materials effects a large saving in the cost of erection and greatly accelerates completion, which obviously shortens the time during which the capital invested remains unproductive.

If the materials are delivered by water, one crane may probably suffice, but in a large work, recently completed where the deliveries were made by rail, it was found more economical to have an ordinary hand-power derrick crane, at the land end, to receive and store, and a portable steam derrick crane at the erecting end, the materials being loaded on trollies by the hand crane and sent on to the front as required.

FIXED DERRICK CRANES.--The drawback to these, at the erecting end, is that they have to be dismantled and re-erected for each move forward, or pinched by hand along a not too solid decking. There is also the liability to be carried away during heavy storms.

The cranes usually employed are 5 to 10 tons power, the length of the jib being 30 to 40-ft. or more, according to the work to be performed.

The prices of derrick cranes, of the type Figs. 5084 and 5124, with jib 40 to 50-ft. long, are approximately as follows:

To lift 5 tons	...	Hand power, £96.	Steam power, £320.
,, 10 tons	..	,, ,, £175.	,, ,, £530.

PORTABLE DERRICK CRANES.—The mast and two back ties are carried on bogies and the crane is moved forward by its own steam power, or by hand, as the work progresses, or is run back for protection in rough weather.

LOCOMOTIVE STEAM CRANE, with PILE SCREWING APPLIANCES. This combination is illustrated and described at page 45, and similar arrangements may perhaps be advantageously adopted under circumstances differing from those specifically described.

WINCHES for screwing and handling Piles are referred to in Section II. of this series.

For Steam Winches, see pages 160 to 163.

For Hand Winches, see pages 169 to 172.

SCREW MOORINGS.—The system is so well known that brief mention of the principles involved will suffice to indicate the kind of information required for determining dimensions, if these cannot be specified by the purchaser.

Sizes of mooring screws.—The size of the screw depends on the nature of the ground and the conditions to be fulfilled, and this again affects the size of shank, shackle, mooring chain, etc.

Fixing mooring screws.—The screws can often be put down from barges, or from sailing vessels of small tonnage. But if there is much swell a fixed staging may be required.

Plant for screwing moorings must frequently be specially arranged to suit local conditions, and may be rather expensive, especially if the moorings have to be screwed in a muddy bottom and in deep water.

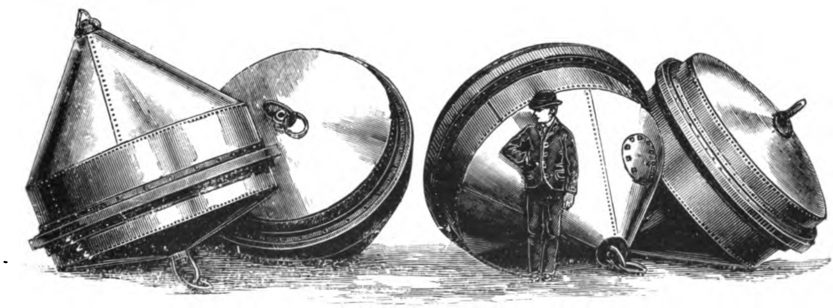


Fig. 5144.

BUOYS.—These vary so much in size, shape and details of construction that they cannot be adequately illustrated in the space available, but Fig. 5144 represents the pear shaped buoy which is largely used in harbours.

The price of a mooring buoy for mooring vessels up to 2000 tons, with screw, 20 fathoms of 2¼-in. chain, ring, shackle, etc. is about £120

Moorings in rivers and tidal waters are usually of the barrel or drum type.

For marking channels the shapes and arrangements of buoys are very varied, Bell, Beacon, or flashlight buoys being frequently necessary. Any of these can usually be obtained soon after information has been supplied similar to that mentioned under the heading "screw moorings."

BRIDGE CONSTRUCTION AND ERECTION.

Although the adoption of standard designs and tests for railway bridges of equal span and width is scarcely a matter for discussion in these pages, reference may be made to some remarks in a paper by Mr. J. Graham, M. Inst. C.E., on "Economies in bridge design and manufacture," in which he points out that much time and money would be saved in both construction and erection if standards were generally (instead of exceptionally) adopted in this country, similar to those which, for many years, have been in use in the United States of America.

Designs and specifications.—If plate girders and deck bridges were accepted as the standard construction for spans up to 75 feet, and framed girders for both through and deck bridges for spans of from 75 feet to 250 feet, standards for tests of materials being also agreed, specifications, drawings, templates, quantities, and in fact all details, could be prepared for single and double track bridges, for each of the gauges in general use, with immense saving in drawing office expenses as well as in cost of construction and erection.

Plate and framed girders.—Mr. Graham also proposes that the plate girders should, of course, be designed in accordance with the latest practice, but in regard to framed girders, an effort should be made to have the cross girders, rail bearers, diagonal bracings and deck flooring common to all spans ranging from 75 feet to 250 feet.

Length of panels.—The best panel distance is a matter for consideration; say 25 feet is adopted as the standard length, then a 75 feet span would be a queen or three panel truss, a 100 feet span would be a four panel truss, and a 250 feet span a ten panel truss.

Plant for erection.—Apart from the fact that stocks could be kept for the deck system of bridges for all the standard spans, it would enable, also, standard arrangements for erection abroad to be prepared and supplied by the contractors, to be either returned to them or transferred from one railway to another.

Methods of erection.—In tropical countries ordinary bridges are constantly erected over a dry, or practically dry river bed, and the writer's experience is that one of the most rapid methods of erection is to have a staging strong enough to support the span, with light towers at each panel post arranged to telescope, and in segments when of considerable height, these towers being spanned by light trusses carrying a rail on top over which a Wellington traveller runs, dealing with every member of the span.

The trucks run up to rail head and the materials are lifted then direct into place on the bridge, there and then.

This method has been described because it shows how much standard panel distances are desirable.

GIRDER YARD ERECTING PLANT.—Overhead travelling cranes or Goliath cranes of the type Fig. 5008, with the necessary clearances in height and span are frequently very useful in girder, boiler and engineering works, but for general service a 3 or 5 ton locomotive steam crane which hauls its load and travels to any part where crane power is required, is extremely useful.

The mode of working in the case illustrated by Fig. 5145 was as follows:

The materials prepared in the girder shop were placed on low trolleys by an overhead travelling crane, and hauled by the locomotive crane to the site for erection in the builder's yard where they were at once put into position or laid on one side of the central track, as convenient The main girders having been erected, the cross girders were laid in, commencing with the front and working back until all were in place as shown in the engraving, and the bridge ready for painting, marking, etc. as mentioned at page 209.

Efficiency of plant.—The time occupied in erecting a number of spans, each 146 feet long, painting, marking, and delivery to clear the ground for the next span, was 6 working days.

The short time in which the work was accomplished was due to the intelligent manner in which the facilities afforded by the crane were used. These facilities consist of steam motions for lifting, slewing, altering the radius of jib, and for travelling, all being controlled in any combination by the driver, so that each portion of the structure was quickly and accurately placed and secured in position.

General service.—The crane is of course available for all purposes, including haulage and loading or discharging wagons, or overside.

The price of a crane of 3 tons power with the above-named motions is usually about £400

A similar crane, but of 5 tons power costs about £500

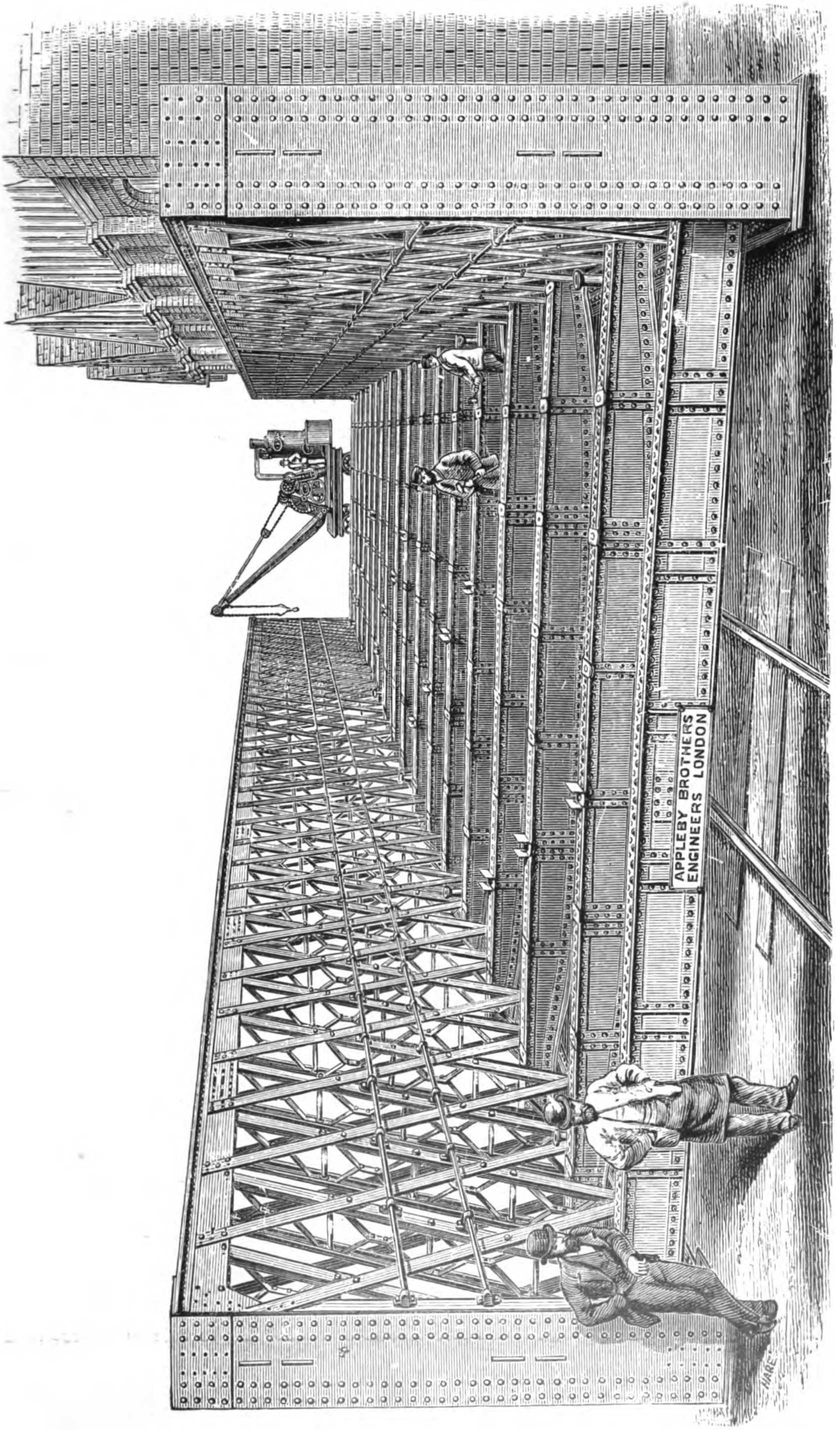


Fig. 5145.

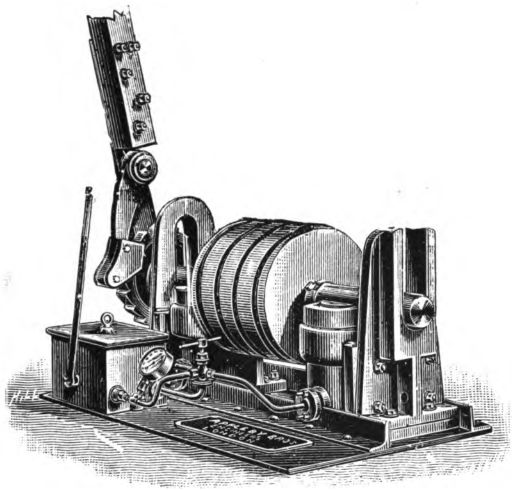


Fig. 5145A.

ROLLER JACK BRIDGE LAUNCHING PLANT.—The hydraulic jacks with roller head, illustrated by Fig. 5145A, is an essential feature in (so far as the writer knows) an entirely novel system of plant which he designed for use under the following rather exceptional circumstances.

Spans and location.—The bridge is in three spans, each of about 175 feet, or 525 in all, the total weight being about 340 tons.

The materials must all be delivered on one side of the river which is usually dry, or nearly so, but is at times a torrent; the bed is hard rock and the piers very high, so that temporary staging or floating plant of the kind illustrated by Figs. 5146 and 5147 were alike impracticable. It was therefore decided to rivet up the main girders and provide for launching them on to their respective seats, commencing with the further span, the central and that at the erecting end following in sequence.

Plant employed.—This consisted of ten twin ram hydraulic jacks, the heads of which form bearings for the steel shaft which carries a steel roller of 24 inches diameter. The grooves in this roller are spaced to clear the heads of rivets in the bottom boom and give a smooth rolling surface and fair bearing on the boom plates.

The standards at each end act as guides for the roller shaft, and the rachet wheel and pawl are used for propulsion as will be presently described.

A pair of jacks, each with hydraulic pumps and all accessories (one jack for each main girder) are fixed in the erecting yard and another pair respectively on the abutment, on each pier, and on the opposite abutment, all in line and spaced to carry the two main girders.

LAUNCHING AND PROPELLING GEAR.—The girders having been rivetted up on packings, just to clear the rollers, and a few cross girders put in for staying and tying, (sufficient counterweight being attached to the after end of the span to prevent the overhanging end from tipping), the jacks are set to work and lift the span clear of the packings.

The span being then ready for launching, the propelling gear is brought into operation. This consists of a steel ratchet wheel keyed on the end of the roller axle, a weighted pawl and long pole with shoe at the lower end to carry the pawl and fulcrum pin.

Each pole is worked by two men, and the pawl engaging the ratchet wheel when the pole is drawn down, the roller is partially rotated and the bridge gradually moved forward. This operation is repeated until the end of span is over its seating, the latter being built up before the jack is withdrawn.

The men worked by signal, and if one end of a span was too low to ride on the roller, a few strokes of the jack pump quickly raised it to the proper height.

Tests.—As there might be about 120 tons on each pair of jacks, each jack was tested to a pressure of 100 tons, or 200 tons for the pair.

No record has reached England of the cost, or of the time occupied in erecting the bridge, but it is known that both cost and time were very much less than had been estimated by either the Engineer-in-Chief or the Contractor.

SPECIAL CRANES FOR BRIDGE ERECTION.—In addition to the hydraulic launching and the floating appliances last referred to, brief mention may be made of plant for erecting long span cantilever bridges, by using the constructed portion as the support or the erecting machinery without the aid of staging or floating plant.

A portable derrick or other form of crane, with jib of sufficient length and height to erect one panel, is carried on temporary rails laid on the bottom booms: this is advanced as the panels are completed and answers every purpose.

The under carriage consists of a temporary staging of the height and span necessary for trucks bringing up materials to pass under it ; and so avoid possible inconvenience in slewing the jib round for its load.

To provide for contingencies of this kind the derrick carriage or tower has been as much as 100 feet high, with clearance at floor level for trucks with materials to be brought to the front. The hoisting machinery may be on the carriage or tower, but it is usually preferable to fix it on a separate carriage at a distance in the rear.

A special crane of suitable construction is sometimes carried on the top booms and anchored —when in use—over the vertical posts of the trusses, the machinery being on a separate carriage on the bottom booms from which all motions are controlled.

Hand-power Goliath cranes of various types have been largely employed, but the arrangements for erecting work of this kind are so diversified, that attention can be directed to only a few examples of plant of special type which have been successfully employed.

FLOATING PLANT FOR BRIDGE ERECTION.—The engravings, Fig. 5146 and Fig. 5147, showing, respectively, a main girder rivetted up complete and ready for erecting, and the girder placed on its seatings on the cylinder piers, serve to illustrate plant designed and built by the writer which was employed in successfully and expeditiously erecting a bridge consisting of a number of spans each of 136 feet, over a river where the depth of water and any interference with navigation precluded the use of staging.

Materials and delivery.—The cylinders and girders (built by the writer's firm) were shipped in pieces of size and weight suitable for handling and delivery at the erecting ground. A temporary jetty was built at this point, with deep water on each side, so that barges could lay alongside when discharging, as well as those for receiving the finished work as will be described later on. This jetty was in still water, about 600 yards above the site of the bridge.

Plant employed.—The cylinders were put down in the usual manner, the mud, sand, etc. being taken out by grab bucket, and the cylinder then filled with Portland cement concrete.

Rivetting.—This was done as far as possible, before shipment ; the top and bottom booms of the main girders were sent out in lengths convenient for stowing and handling and these were rivetted up, together with the bracings after delivery, on the above-named jetty, from which each complete girder was transferred to the barges, these being equipped with appliances for raising the girder to the height required as shown in the engravings.

Lifting plant.—This consisted of a strong tower, similar in construction to a pile-driver frame, fixed on each barge with powerful steam winch behind as seen in Fig. 5147.

The girder, having been placed on the barges and temporarily lashed to the towers, was floated or towed into position, when the steam winches were set to work and in a few minutes the girder was deposited on its seatings, as shown in the engraving. This having been shored, the opposite girder was erected in a similar manner and permanently secured by the top bracing, cross girders, &c.

RIVETTING PLANT.—It may be well to mention that skilled labour being scarce and very expensive, a portable hydraulic rivetting plant of the type shown in Fig. 3083 sent out, and by the aid of this and the lifting plant, the bridge was (Section IV.) erected quickly and at small cost.

Since the work now referred to was completed, the same plant (with sundry modifications) has been employed in the erection of many other structures, but pneumatic plant (not obtainable at that time) would have been more convenient and certainly more generally useful.

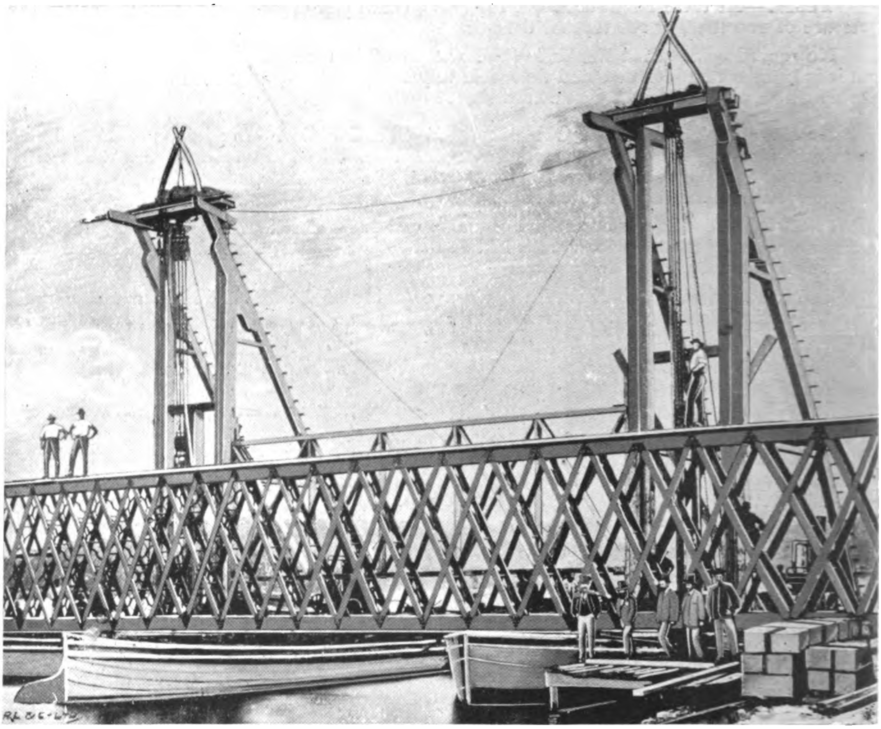


Fig. 5146

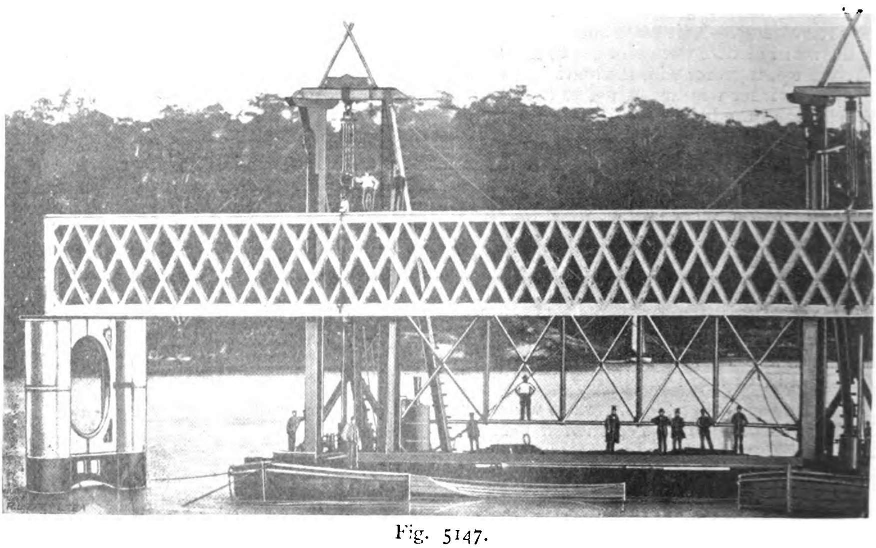


Fig. 5147.

PORTABLE PNEUMATIC RIVETTING PLANT.—The arrangement now briefly described was devised and successfully used for strengthening and repairing bridges on a main line of railway, much of the work being of a nature which could be most conveniently executed at the site.

Plant employed.—The machinery is mounted on an ordinary railway wagon and consists of rivetting hammers, a gap rivetter, drillin machine, and a chipping hammer, all worked by pneumatic pressure, generated (in this case) by steam power, the engine, boiler, air compressor and receiver, water tank, rivet hearths, &c. being carried on the wagon, so that the installation can be located alongside the work in hand, or at a distance from it as may be desirable.

More recent installations have been driven by a gas or oil engine, with a small pump for supplying water to cool the air compressor and engine cylinders.

The air is conveyed to the machines by iron tube 1 inch diameter with flexible hose and connections, so that they may be used in the most convenient position.

Advantages.—These are rapidity (always an important feature) but perhaps the principal advantage is that—if the plant is in charge of a good foreman—little or no skilled labour is required, even for rivetting.

One man working a pneumatic drill will do as much (and more) work than can be done by five or six men drilling by hand.

Two men with a pneumatic rivetter will put in more rivets, and the quality of work will be superior to that done by three men hand rivetting.

The cost of a set of machines similar to those now referred to will probably be about ... ... £350 to £450

Fig. 5148

CRANES FOR BRIDGE RENEWALS.—One or two portable or (by preference) locomotive steam cranes, as represented by Fig. 5148, are of great service. The advantage of two cranes, when erecting renewal bridges, is that one can be used in the rapid demolition and removal of the old bridge, whilst the other is employed in preparing the new work for putting into place, and the power of both can be concentrated in handling pieces too heavy to be safely dealt with by one of them.

STEAM CRANES.—That now illustrated is of 10-tons power, complete with all accessories for hauling wagons and for running with ordinary rolling stock, and is reproduced from a photograph taken during a Sunday bridge renewal on an important main line.

Advantages of steam motions.—It is claimed that a steam crane worked by one man will do more work in a given time than can be got through by twenty men working hand cranes, and where the local supply of labour is as limited as it usually is, this alone is an important consideration.

The steam travelling motion admits of the crane being moved quickly without the aid of a locomotive or horses, where either of these would be highly inconvenient.

Facilities for altering the radius or reach of the jib, with even a moderate load suspended, are always desirable and sometimes invaluable.

Another and more modern construction of crane for this duty is illustrated at page 114, this has a lower centre of gravity and affords the driver better supervision of the load and surroundings, but both are largely employed in railway service and approximate prices for both types will be found below and at pages 45 to 51 of Section II.

LIFTING POWER AND RADIUS OF JIB.—Although most of the loads may be comparatively light, it is always convenient to have ample margins of strength, and for this reason, many of these cranes are of 10-tons power. To ensure stability, however, when working at an angle with the track, it is rarely desirable for the radius of the jib to exceed 16 to 18-feet.

Variations in equipment.—Cranes of both types are built with straight or curved jibs, with or without derrick motion, and some other variations which naturally affect the cost, but the subjoined figures represent the approximate cost with usual equipment, and it may be well to point out that two cranes of 10 or 15 tons power, may some times be more generally useful that one equal to a load of 20 or 30 tons.

PRICES OF PERMANENT WAY STEAM CRANES.

Power of crane ... ... tons	5	7	10	15
Price of crane, Fig. 5148	£600	£700	£1100	£1350
,, Fig. 5085	£580	£650	£1000	£1200

HAND POWER CRANES.—Illustrations and many details relating to these are given at pages 71 to 81 of Section II. See also page 111 of this section.

ERECTING RENEWAL BRIDGES.—This (usually Sunday) work must always be done in the shortest possible time, and the design of bridges, weights of pieces, the time during which traffic can be wholly or partially interrupted vary so widely that, at first sight, it would appear that the plant employed must be greatly diversified. To a certain extent this is so, but considerable experience goes to show that in reality the plant for erecting bridges of ordinary span needs to vary in quantity and power more than in kind.

The object however of these remarks is to direct attention to some points which are not always kept in mind, either in the drawing office or the girder yard.

Design.—In view of the paucity of labour locally, and the short time during which operations can usually be carried on continuously, they are obviously greatly accelerated by designing the parts in as large pieces as can conveniently be handled at the site for erection, or for final rivetting up and fixing.

Inattention to these details has, in the writer's experience, far more than doubled the cost and time for handing bridges over for traffic which were practically identical in span, carrying capacity and local conditions.

Distinguishing marks.—Time spent in completely marking the various members, before delivery, almost invariably means time and money saved in erection, but if not wholly neglected, this is sometimes done less carefully and intelligently than it might be, whilst if the precautions above referred to are taken, much loss of precious time in seeking and assembling parts is avoided. The writer's practice has been to paint the parts which do not come together, in different colours, for instance: one main girder of a span may be painted red and the other green, the ends (or half) of the cross girders corresponding in colour with that of the main girder to which it has been fitted. Other spans are, of course, treated in a similar manner and even as far as necessary, the kegs or packages containing service bolts, rivets, etc. are marked in colours corresponding with the parts to which they belong.

If these precautions are taken many valuable hours are saved in seeking and assembling the parts, even if the erectors have been employed on the work in the builder's yard—and more if it is taken up by strangers.

Attention may also be directed to the remarks at page 203 on uniformity in design.

Siding tracks.—If cross-over roads are at some distance from the bridge, or when the renewal occupies a considerable time, involving temporary traffic arrangements at that point on a single line, much trouble and expense in signalling may be avoided by laying in a temporary siding, and connecting it by a cross-over road to the main line before commencing the renewal of the remaining portion of the bridge.

Such temporary sidings and connections with the main line can usually be put in ready for storing the new materials prior to commencing erection ; they also serve for marshalling the wagons which carry away the old materials after they have been removed.

BRIDGES ERECTED BY PURCHASERS.—The preceding remarks with reference to distinguishing colour apply very directly to work for export, or for being dealt with frequently by men without any sort of training or experience, and who even do not know how to use a two-foot rule.

GANTRY CRANE FOR ERECTING LONG SPANS.—The plant now referrred to is an example of special lifting appliances for erecting a railway bridge with 250 feet spans. The piers are in concrete carried up from rock foundations, wrought-iron caisson and air-compressing plant (see Figs. 5117 to 5119) being employed in their formation.

The depth of the girders is 30-ft. 9-in. at the centre and 16-ft. 6-in. at the ends.

The gantry used in the erection of the posts, top booms and diagonals was a travelling platform carrying a tower about 43 feet high and an arm projecting horizontally on each side provided with jenney (and gear for traversing it about 12 feet) for the purpose of picking up the materials and traversing them into position for erection.

The platform and tower are mounted on four trolleys which travel on tracks laid on the temporary decking, two hand winches fixed on the platform are provided for lifting—one for each arm—the loads being traversed along the arm into position for erecting by racking gear worked from deck level by hauling on an endless chain.

This plant was devised by the engineer in charge of the work and handled the heaviest section with perfect safety and great economy.

BRIDGE BUILDING AT SITE.—This system, involving as it does the erection of buildings and working plant, and frequently accommodation for workmen and staff, has been adopted in building large bridges on the continent of Europe, it is claimed, with considerable success due to savings in cost of transport, handling, etc. The most notable and successful example of this in any country is, however, the Forth Bridge.

This subject is mentioned chiefly to direct attention to the facilities now at disposal in the electric transmission of power, and appliances worked by pneumatic pressure for many operations incidental to the construction of bridges as near as possible to the site where they are to be erected.

HAND POWER GOLIATH CRANES FOR BRIDGE ERECTION.—Several cranes for this purpose have been built to designs specially prepared under instructions from an experienced bridge erector.

These cranes have a clear span of 22-ft. and a height of 21-ft., and are provided with two traversing crabs each of 3 tons power, which are worked from platforms on each side of the main girders.

The under-carriages are fitted with hand power propelling gear and the cranes (which spanned the width of the bridge) lifted and placed in position the main girders and the rest of the work, at very low cost for labour. When the lines were completed the cranes were available for station service.

The framework (Gantries) of the earlier cranes were built of pitch pine timber, but those more recently constructed are of steel.

The price of each crane with timber frame is about £200

If with steel framework, the price is about £230

The cost of ironwork, includlng grabs, travelling gear, blocks, chains, etc., ready for mounting on timber framework, is about £165

It will be scarcely necessary to mention that cranes of this type and to work from above, as those described, or from ground level, are built of any power or span.

ROOF ERECTION.—When the writer co-operated in the design and arrangement of the staging and plant illustrated by Fig. 5149, used more than 30 years ago in the erection of the roof of the Midland Railway Terminus at St. Pancras, he little thought that it would serve as the basis for the design of very many other installations subsequently employed, with marked economy in the cost, and in the time required for the erection of roofs of large dimensions.

The staging was built of timber, the useful and convenient sections in iron and steel of reliable quality now available, being, at that period, non-existent. But the plant answered its purpose so well, that the work was completed with a rapidity and economy then unparalleled, and without loss of life or limb.

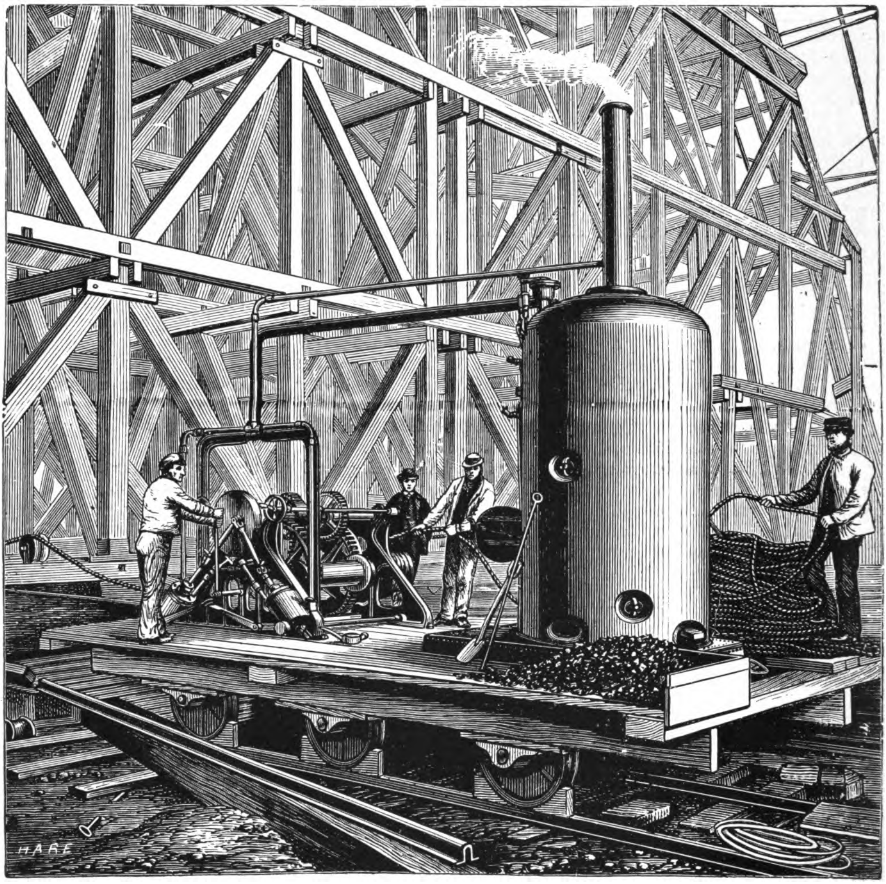


Fig. 5149.

Machinery.—A double cylinder steam winch with duplex barrels was fixed at one end of the trolley and a vertical cross tube boiler at the other. The intervening space was ample for coiling rope or chain, and the trolley was hauled forward as the work progressed.

The lifting barrels could be worked singly, or together, in single or double purchase, and the ends of the barrel shafts carried grooved capstan ends of large diameter, which were used chiefly for the high lifts.

Tool trolley.—To avoid the inconvenience and loss of time incurred in sending away parts requiring minor alteration, tools for repair, &c. a second trolley was provided and equipped with a blacksmith's forge, drilling machine, punching machine, vice bench, and sundry fitters' tools. This was attached to the machinery trolley and fully answered the purpose for which it was provided.

GIRDERS & BRIDGE BUILDING MATERIALS.

A considerable amount of information relating to structural steel work will be found in the following pages and this is supplemented by a few examples of the approximate cost of the bridges referred to, although it is really impossible to deal at all adequately with structures which must necessarily vary in innumerable details.

BOW STRING GIRDER BRIDGE, 120-ft. SPAN.—The roadway is 14-ft. wide and the bridge is suitable for road or railway traffic to carry a rolling load of about 20-tons.

The bridge is built of steel with buckled plates between the cross girders and costs about £1300

LATTICE GIRDER BRIDGE, 120-ft. SPAN.—The roadway 14-ft. wide and the floor is laid in concrete. The cost of the steel work with neat side railings, painted and marked and for re-erection is about £950

LATTICE GIRDER BRIDGE 36-ft. SPAN and roadway 13-ft. 6-in. wide with steel trough flooring and suitable for country road traffic. The cost of the steel work painted and marked for re-erection is about £250

STEEL PLATE GIRDER BRIDGE 42-ft. SPAN and 24-ft. wide with close lattice work protection on each side.

The bridge is constructed to carry a traction engine or other heavy road traffic ; the roadway is carried on steel trough flooring and the cost is about £350

CURVED STEEL GIRDER BRIDGE 75-ft. SPAN and 12-ft. wide ; the roadway is carried on steel buckled plates and is used for carriage traffic.

The cost of the bridge with neat side railing is about £550

OVERHEAD LATTICE GIRDER FOOT BRIDGE 40-ft. SPAN and 5-ft. wide, with stair way on each side and supported on cast or wrought iron columns, costs about £250

A similar bridge, but with galvanised iron roof and close boarding on both sides and glazed for lifting costs about £350

WIRE ROPE SUSPENSION BRIDGES for foot passenger or animal traffic, are built for spans of 50 to 300 feet, with platforms usually 4 feet to 6 feet wide, and capable of sustaining a distributed test load of 160-lbs. per square foot, or about twice the weight of the people who could stand on it.

The towers which carry the steel wire ropes and suspension rods are constructed of steel sections with lattice bracing, and present a neat appearance.

Weights of parts.—With the exception of the base plates for towers and the coils of steel wire suspension rope, the separate parts are quite light aud easily handled.

Cost of bridges.—The whole of the metallic work, including the special tools required for erection, ranges from about £130 for a bridge of 50 feet span and 4 feet wide, to about £650 for one of 300 feet span and 6 feet wide.

The timber work in the platform is usually supplied by the purchaser.

A bridge of 200 feet span and 6 feet wide (including the above-named tools) can be obtained for about £420 and the total weight of steel and ironwork is about 8¼ tons.

Information required.—In addition to the span and clear width of platform required, a sketch, with figured dimensions, should be furnished showing the section between banks, and the space on them available for towers and attachments.

The nature of the formation on which the towers will be erected should be accurately defined.

STEEL AND WROUGHT IRON GIRDERS.

The following tables give the approximate weight in lbs. per foot run for girders of different spans, depths and sections, built of Siemens-Martin steel, also the safe distributed load (in tons) for girders supported at both ends.

The girders have stiffeners at intervals, and countersunk flush head rivets at bearings, and are constructed throughout to Board of Trade regulations.

Live Loads, or dead loads concentrated on the centre of girders supported at both ends, must not exceed one-half of those tabulated.

Cantilever girders (supported at one end only) should not be loaded to more than one-fourth of the weights given in the tables for distributed load, or more than one-eighth for a rolling or central load.

Wrought-iron girders must not be loaded to more than five-sevenths of the weights given for steel girders.

Prices of girders.—With normal rates for materials, steel girders of the types referred to, with edges of plates planed and rivets closed by hydraulic or other machine, can usually be obtained at £14 to £15 painted and delivered on trucks at works.

If the rivet holes are drilled the extra cost is usually 6/- to 9/- per ton, but—if time permits—it is more satisfactory to have definite quotations for the quantities, sections and dates of delivery required.

SECTIONS, WEIGHTS, AND STRENGTHS OF ENGLISH ROLLED STEEL GIRDERS.

Fig. 5150.

Size of Section. Depth	Width	Approx. Weight per Foot in lbs.	Clear Span, in Feet, between Bearings. 6	8	10	12	14	16	18	20	22	24	26	28	30
ins.	ins.														
20 ×	$7\frac{1}{2}$	89	195	146	117	97	83	73	65	58	53	48	45	41	39
18 ×	7	75	151	113	90	75	64	56	50	45	41	37	34	32	30
16 ×	6	62	107	80·2	64·2	53·5	45·8	40·1	35·6	32·1	29·1	26·7	24·6		
15 ×	5	42	65	49·1	39·3	32·7	28 0	24·5	21·8	19·6	17·9	16·3			
14 ×	6	57	88	66	52·8	44	37·7	33	29 3	26·4	24	22			
14 ×	6	46	71·5	53·6	42 9	35·7	30·6	26·8	23·8	21·4	19·1	17·8			
12 ×	6	54	73	54·7	43·8	36·5	31·2	27·3	24·3	21·9					
12 ×	5	39	50·1	37·6	30·1	25	21 5	18·8	16·7	15·0					
12 ×	5	32	41·5	31·1	24·9	20·7	17·8	15·5	13·8	12·4					
10 ×	6	45	51·1	38·3	30·7	25·5	21 9	19·1	17·0						
10 ×	5	35	37·8	28·3	22·7	18·9	16·2	14·1	12·6						
10 ×	5	29	33·5	25·1	20·1	16·7	14·3	12·5							
9 ×	$3\frac{3}{4}$	24	23·3	17·5	14 0	11·7	10·0	8·8							
9 ×	$3\frac{3}{4}$	20	19 6	14·7	11·8	9·8	8·4	7·3							
8 ×	6	35	33·0	24·7	19·8	16·5	14·1								
8 ×	5	30	27·6	20·7	16·6	13·8	11·8								
8 ×	4	25	21·3	16·0	12·8	10·6	9·1								
8 ×	4	19	16·6	12·5	10·0	8·3	7·4								
7 ×	$3\frac{3}{4}$	20	15·1	11·3	9.1	7·5									
7 ×	$3\frac{3}{4}$	18	14·1	10·6	8·5	7·0									
7 ×	$3\frac{3}{4}$	16	12·2	9·1	7·3	6·1									
6 ×	5	25	17·4	13·1	10·4										
6 ×	$4\frac{1}{2}$	20	13·1	9·8	7·9										
6 ×	3	16	10·0	7·5	6·0										
6 ×	3	13	8·2	6·1	4·9										
5 ×	$4\frac{1}{2}$	23	12·7	9·5	7·6										
5 ×	3	15	7·6	5·7	4·5										
5 ×	3	13	6·8	5·1	4·1										
5 ×	3	11	6·4	4·8	3·8										
$4\frac{3}{4}$ ×	$1\frac{3}{4}$	10	4·1	3·1											
4 ×	3	12	5·3	4·0											
4 ×	$1\frac{3}{4}$	8	3·0	2·3											
$3\frac{1}{2}$ ×	$1\frac{1}{2}$	6	2·0												
3 ×	3	10	3·3												
3 ×	$1\frac{1}{2}$	5	1·3												
3 ×	$1\frac{1}{4}$	4	1·1												

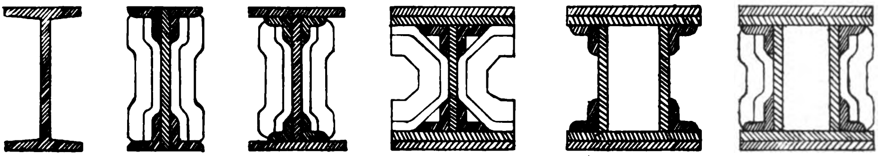
Notes on Safe Loads.

This Table indicates the safe loads, in tons, which may be placed on the various girders, provided the loads are distributed equally along the whole length of the girder. Should the whole of the load be concentrated in the middle of the girder, or is moved along it, the safe load so applied should not exceed half that given in the table. If the girder is firmly fixed at one end, and supported at the other, *i. e.* cantilever, and the load equally distributed, it will carry one-fourth of the load given in the table. If the load travels, or is concentrated at the unsupported end, it will only carry one-eighth of the tabulated load.

The weight of the beams has not been taken into account in making the calculations of their bearing capacity.

The above safe loads are calculated at one-third of the breaking weights.

RIVETTED GIRDERS.



Figs. 5150. 5151. 5152. 5153. 5154. 5155.

SINGLE WEB STEEL GIRDERS, WEIGHTS AND LOADS, TYPE FIGS. 5151 AND 5152.

Depth and width, inches	Weight per foot.	Span in feet and safe distributed load in tons.								
		12	16	20	22	24	27	30	35	40
12 × 8	62 lbs.	26·2	19·6	15·7	14·3	13·1	11·6	10·5	9·0	7·8
15 × 8	66 ,,	33·7	25·3	20·2	18·4	16·9	15·0	13·5	11·6	10·1
18 × 8	82 ,,	45·6	34·2	27·4	24·9	22·8	20·3	18·2	15·6	13·7
18 × 12	117 ,,	72·2	54·7	43·3	39·4	36·1	32·1	28·9	24·8	21·7
21 × 12	126 ,,	87·5	65·6	52·5	47·7	43·7	38·9	35·0	30·0	26·2
21 × 12	168 ,,	132·5	99·3	79·5	72·2	66·2	58·9	53·0	45·4	39·7
24 × 12	131 ,,	100·6	75·5	60·4	54·9	50·3	44·7	40·2	34·5	30·2
24 × 12	173 ,,	151·5	113·6	90·9	82·7	75·7	67·5	60·6	51·9	45·4
24 × 16	214 ,,	186·7	140·0	112·0	101·8	93·3	83·0	74·7	64·0	56·0

SINGLE WEB STEEL GIRDERS, WEIGHTS AND LOADS, TYPE FIG. 5153.

Depth and width, inches	Weight per foot.	Span in feet and safe distributed load in tons.								
		20	24	27	30	35	40	45	50	55
27 × 12	132 lbs.	65·2	54·3	48·4	43·5	37·3	32·6	29·0	26·1	23·7
27 × 15	156 ,,	74·9	62·4	55·5	49·9	42·8	37·4	33·3	30·0	27·2
30 × 12	137 ,,	72·7	60·6	53·9	48·5	41·6	36·4	32·3	29.1	26·5
30 × 16	229 ,,	139·3	116·1	103·2	92·9	79·6	69·6	61·9	55·7	50·7
36 × 13	159 ,,	96·2	80·2	71·3	64·1	55·0	48·1	42·8	38·5	35·0
36 × 17	249 ,,	175·8	146·5	130·2	117·2	100·5	87·9	78·1	70·3	63·9
42 × 14	173 ,,	117·6	98·0	87·1	78·4	67·2	58·8	52·3	47·0	42·8
42 × 17	265 ,,	209·9	174·9	155.5	139·9	119·9	104·9	93·3	83·9	76·3
48 × 18	286 ,,	251·2	209·3	186·1	167·5	143·6	125·6	111·7	100.5	91·3

BOX SECTION STEEL GIRDERS, WEIGHTS AND LOADS, TYPE FIG. 5154.

Depth and width, inches	Weight per foot.	Span in feet and safe distributed load in tons.								
		12	16	20	22	24	27	30	35	40
12 × 14	114 lbs.	47·6	35·7	28·5	25·9	23·8	21·1	19·0	16·3	14·3
15 × 14	120 ,,	60·8	45·1	36·0	32.8	30·0	26·7	24·0	20·6	18·0
18 × 15	182 ,,	126·5	94·9	75·9	69·0	63·3	56·2	50·6	43.4	38·0
21 × 16	202 ,,	155·9	116·9	93·5	85·0	77.9	69·3	62·3	53·4	46·8
24 × 18	312 ,,	291·8	218·8	175·1	159·1	145·9	129·7	116·7	100·0	87·5

BOX SECTION STEEL GIRDERS, WEIGHTS AND LOADS, TYPE FIG. 5155.

Depth and width, inches	Weight per foot	Span in feet and safe distributed load in tons.								
		20	24	27	30	35	40	45	50	55
27 × 18	251 lbs.	138·5	115·4	102·6	92·3	79·1	69·2	61·5	55·4	50·4
30 × 18	330 ,,	215·3	179·4	159·4	143·5	123·0	107·6	95·7	86·1	78·3
36 × 19	360 ,,	270·4	225·3	200·3	180·2	154·5	135·2	120·2	108·1	98·3
42 × 20	393 ,,	333·7	278·1	247·2	222·5	190·7	166·9	148·3	133·5	121·4
48 × 20	411 ,,	380·6	317·2	281 9	253·7	217·5	190·3	169·2	152·3	138·4

STEEL OR IRON FLOORING PLATES, of the section, width and shape required for bridge and warehouse floors, are made of varied forms and strength to carry distributed loads from about 5¼ to 23 cwt. per square foot of area, and are frequently used in lieu of cross girders.

This arrangement gives increased headway and the joints being lapped, or made with butt strips, and rivetted, the flooring is quite watertight. It can also be used for spans not exceeding 20 feet without cross girders.

BUCKLED AND CURVED FLOORING PLATES are made of almost any size and thickness.

ROLLED STEEL VALLEY OR GUTTER GIRDERS are made in sections varying from 8-in. wide overall and 4-in. deep, weighing about 28-lbs. per foot run, to 23-in. wide and 12-in. deep, weighing 88-lbs. per foot, and—as girders—carry loads in proportion with their sectional area, frequently dispensing with the use of columns and girders of the ordinary type.

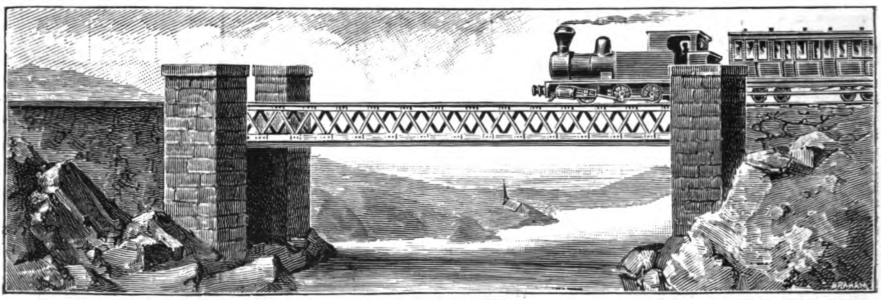


Fig. 5156.

LATTICE GIRDER BRIDGES FOR LIGHT RAILWAYS.—The following tables of dimensions, safe live load, and approximate cost of bridges of the type indicated by Fig. 5156, suitable for locomotive or animal traction, foot passengers or vehicles, will serve for purposes of preliminary estimate.

Construction.—The girders are steel rolled sections, lattice braced with holes in the top flanges for fastening the timber decking, but as this can usually be obtained locally, decking and hand rails are not included in the subjoined estimates of cost. Sleepers may be dispensed with by spiking the rails to the wood floor.

PRICES OF STEEL LATTICE GIRDER BRIDGES.

Length of girders	feet	30	50	70
Safe live load	tons	14	18	25
Price of bridge	...	£55	£95	£145
Approximate weight of heaviest piece ...	cwt.	15	15	24

WROUGHT IRON PIERS of simple construction and easily erected are supplied where the length of bridge requires two or more spans.

SAFE LOAD FOR STEEL COLUMNS.—See table, page 263.

ROLLED STEEL GIRDER BRIDGES for short spans consist of a pair of I section beams with holes in the top flanges for fastening the planking. If the girders are fixed 5 feet apart the planking may be laid across them to give a platform width of 8 to 10 feet.

Carrying capacity.—The safe live load, in tons, is given for the respective sections and spans.

STEEL GIRDER BRIDGES 12 FEET SPAN.

Section of girders	inches	10 × 4½	10 × 6	12 × 6
Safe live load	tons	17	24	35
Price of bridge	...	£6	£8	£10
Approximate weight per foot	lbs	32	43	56

STEEL GIRDER BRIDGES FOR 14 FEET SPAN.

Section of girders	inches	10 × 4½	10 × 6	12 × 6
Safe live load	tons	14	20	30
Price of bridge	...	£6 15	£9 10	£12
Approximate weight per foot	lbs.	32	43	56

STEEL GIRDER BRIDGE 16 FEET SPAN.

Section of girders	inches	10 × 4½	10 × 6	12 × 6
Safe live load	tons	12½	18	27
Price of bridge	...	£7 10	£10 5	£13 10
Approximate weight per foot	lbs.	32	43	56

STEEL GIRDER BRIDGE, 20 FEET SPAN.

Section of girders	inches	10 × 4½	10 × 6	12 × 5
Safe live load	tons	10	14	21
Price of bridge	...	£10 0	£12 5	£17 0
Approximate weight per foot	lbs.	32	43	56

ERECTING TOOLS, such as hand winch, blocks, chain, spanners, hammers, adze, pick axe, shovels, etc. can be obtained at a cost of £20 to £25.

IRON BUILDINGS.

Although the use of wrought iron in the construction of roofs and buildings dates back only about 40 years, it would be impossible to illustrate, or even enumerate, the different types of these most useful structures which have been erected within that period, in all climates and for all conceivable objects, from a mere lean-to roof, to the most elaborate and extensive buildings for municipal, commercial and residential purposes, railways and docks, churches, factories, warehouses and so forth.

Widely as these buildings differ in design, arrangement and dimensions, the following information may be of some service when questions relating to the approximate cost of useful buildings of given size and construction are under consideration.

The cost per superficial foot covered, with a description of the leading features contemplated is perhaps the most simple way of attaining the last named object, and this basis has been adopted together with tables showing the approximate cost of roofs of different types and spans. Careful expert study may, however, indicate that the best results will be obtained by deviating, to some extent, from the design originally contemplated, and so reduce (or increase) the total cost of the structure.

Information required.—This is best conveyed by a sketch of the roof or building, with figured dimensions, accompanied by data relating to thickness of walls, section of columns, etc. if any existing. Failing this, the details should be described as accurately as possible, together with such notes as may be necessary with regard to climatic and other similar conditions.

Buildings.—Sketches or description should indicate the sizes, positions of doors, windows, etc. and the extent of ventilation required, the height from floor to eaves, or between floors, and, in the latter case, the dimensions and arrangement of rooms most convenient.

The cost of woodwork is not included in any of the approximate estimates (unless so specified). Wood and iron work in combination can frequently be used with advantage and whether the former will be supplied locally, or must be provided with the iron work, should be mentioned.

Painting and packing.—The ungalvanised parts are painted, the small pieces usually packed in cases and the galvanised sheets in skeleton cases weighing about 5-cwt. each, and the roof ties, etc. in bundles. The cost of this and of delivery f.o.b. varies, but is never a serious item.

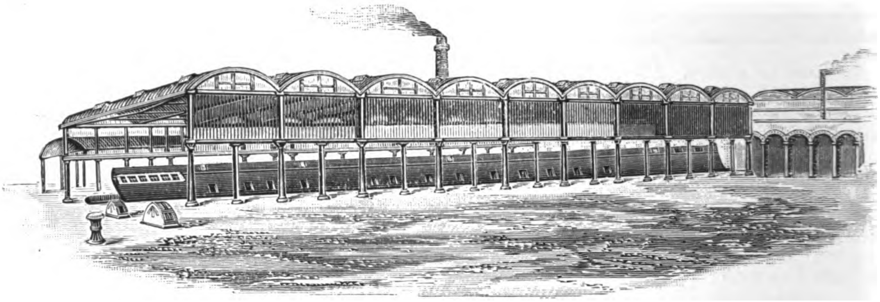


Fig. 5157.

COMBINATION ROOFS TO COVER LARGE AREAS.—The arrangement indicated in Fig. 5157 is economical and convenient for buildings to cover a large area, whether open at sides and ends or entirely (or partially enclosed.) The central portion is constructed as described below.

The cost of such buildings ranges from 1/2 to 2/- per square foot of ground covered.

RIDGE OR PITCH ROOFS.—The roof is constructed of steel, with shoes for fixing to walls, or to iron or timber columns; the purlins are of L steel, and the roof is covered with galvanised corrugated sheets.

Ventilation may be provided by leaving an open space below the eaves, or by having a continuous ventilator above the apex of the roof. The latter adds 3/6 to 4/6 per foot to the cost of the roof.

The columns may be of timber, wrought iron or cast iron, and the cost of the latter, per foot run of shed, will be found below. The height of the columns is estimated at 16 feet, and the distance apart 20 feet.

The following prices, at per foot run, are for a length of not less than 100 feet of roof and this basis has been adopted in making the estimates of approximate cost of each item. Shorter lengths naturally cost rather more per foot run.

PRICES OF RIDGE ROOFS.

Span of roof ... ... feet	25	30	40	50	60
Price of roof ... per foot lineal	18/6	22/-	30/-	39/6	55/6
Approximate weight per 100 feet tons	6¼	7½	10¼	14	19¾
Price of columns per foot of roof ...	...	14/-	17/-	19/6	20/6
,, gutters and down pipes ...	1/1	1/1	1/2	1 4	1/6

WAREHOUSE WITH CURVED IRON ROOF suitable for storing cotton or other inflammable materials and carried on iron columns about 15 feet high, with iron framed partitions and large sliding doors, the whole being covered and completely enclosed with corrugated galvanised iron.

The cost of buildings of large area usually ranges from 1/9 to 1/11 per superficial foot of ground covered.

WAREHOUSE ROOFS ON IRON COLUMNS, as above described, closed at the gable ends, but open all round below for filling in or not, as required, costs about 1/3 to 1/4 per superficial foot of ground covered.

CURVED ROOF RAILWAY STATION SHELTERS.—A line of iron or timber central columns with cantilever brackets on each side, supporting a curved corrugated iron roof, forms an economical structure which frequently answers every purpose.

The cost of a shelter of this type 150 feet long, with iron columns and brackets carrying a galvanised iron roof 12 feet wide, is about 1/3 per superficial foot of ground covered.

The cost of erection, exclusive of masonry or other work on the platform, is usually about 5d. per foot run of shelter.

PITCH ROOF RAILWAY STATION SHELTERS 25 feet wide, supported on iron columns on each side, costs about 1/9 per superficial foot of ground covered and the cost of erection under the above-named conditions is about 6½d. per foot.

RAILWAY AND DOCKS GOODS WAREHOUSES being almost invariably designed to suit local conditions, necessarily vary widely in dimensions, arrangement, number of floors, etc. the cost may range from about 1/9 to 6/- or more per superficial foot of ground covered, but the following examples are selected as of generally useful dimensions, and the average prices of component parts being given elsewhere, there will be little difficulty in estimating the approximate cost of buildings of similar type, but of other dimensions.

CURVED ROOF GOODS WAREHOUSE.—Large numbers have been built about 60 feet long, 30 feet wide and 14 feet high to eaves, with overhanging roof on each side carried by brackets attached to the iron pilasters which support the roof ties and timber bearers to which the iron covering at sides and ends is secured.

Large doors are provided for goods service and one end is partitioned off, with separate door and window to form an office or special storage room.

The cost of such a warehouse with means for ventilation at each end is about 3/- per superficial foot of ground covered, but the ends may be closed and ventilators in the roof provided at a cost of about 18/- each.

For packing, delivery, etc. see page 217.

PITCH ROOF GOODS WAREHOUSE about 90 feet long, 33 feet wide and 15½ feet high to eaves, the latter overhanging and supported by brackets from the iron columns. The interior is lined with tongued and grooved timber and there are large service doors at sides and ends.

The cost of the warehouse is about 3/9 per superficial foot of ground covered.

CURVED ROOF GRAIN WAREHOUSES, timber framed and fixed on short iron vermin-proof columns, and fitted with sliding doors, cost about 3/- per superficial foot of ground covered.

WEAVING SHED ROOFS of the familiar type and about 20-ft. wide have corrugated galvanised iron on one side and lights on the other. The roofs and valley gutters between them are carried on girders supported by iron columns, usually 12-ft. high and 22-ft. apart.

The cost of these roofs is about 1/9 per superficial foot of ground covered ; the cost of erection will probably be about 6d. per foot run of roof.

COTTON GINNING AND PRESSING FACTORY.—Buildings for these or similar operations, to cover an area of 90 to 100-ft. long by about 60-ft. wide, are frequently arranged to receive a steam engine and boiler (or gas or oil engine), with ginning room, press house, repairing shop, stores and offices.

The roofs are of the curved type and fitted with ventilators, the ends and sides enclosed where necessary.

The cost of such a factory with doors, windows, etc. is about 1/8 per superficial foot of ground covered.

PLANTATION BUIDINGS for the storage or treatment of coffee, sugar, indigo and many other products can usually be obtained at about the same cost as ginning factories.

TEA FACTORY BUILDINGS, with upper floor used for withering and the ground floor, with side verandahs, for the rolling, firing, and sifting machines, and for packing, etc. cost from about 1/6 to 2/3 per superficial foot of ground covered.

WITHERING RACKS.—In connection with the last subject it may be convenient to have the approximate cost of racks for the last-named buildings.

Steel racks comprise two uprights with stays at each end and diagonally braced steel supports for the wires at intervals of about 9-ft. together with the necessary galvanised steel wire and straining gear.

The materials for wood racks consist of the necessary galvanised steel wire, straining screws and staples to support the wires. All woodwork is supplied by the purchaser and it may be mentioned that wood racks occupy much more space than steel.

PRICES OF MATERIALS FOR WITHERING RACKS.

Length of rack ... ... feet	27	36	45	54
Price of steel racks	£6 17 6	£7 14 6	£8 11 6	£9 8 6
,, wires, etc. for wood racks ...	£2 0 0	£2 5 6	£2 11 0	£2 16 6

STORE or "GO-DOWN," with ridge roof about 13-ft. high to eaves, fitted with windows and sliding doors and ready for erection on masonry or other foundations, costs about 2/1 to 2/3 per superficial foot of ground covered.

ROOFS FOR COOLIE LINES consisting of steel roof trusses covered with corrugated galvanised iron can usually be obtained at about the following prices.

Curved roofs, 1/- to 1/1 per superficial foot of ground covered.

Ridge roofs, 1/1 to 1/2 per superficial foot of ground covered.

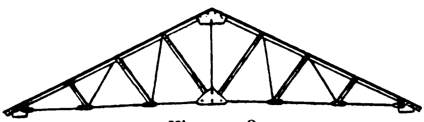


Fig. 5158.

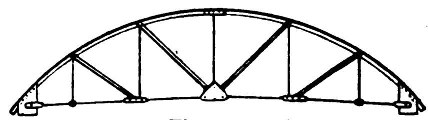


Fig. 5159.

MATERIALS FOR RIDGE OR "PITCH" ROOFS.—The trusses are constructed to carry corrugated iron covering for the respective spans when spaced 10 to 12 feet apart. To save calculation, the tables show the cost of covering per foot run of roof of the respective spans, with sheets of all gauges ordinarily used, including L steel purlins. For temporary use (or for other reasons) the light gauges may answer every purpose, but—as is well known—the heavier sections are far more durable.

Principals to be roofed with slate should be spaced not more than 6 to 8 feet apart. The rise is about one-fourth of the span.

The prices of roofing are based on the cost of recent years, and are, of course, influenced by the fluctuations in the current prices of the materials used.

APPROXIMATE PRICES OF RIDGE ROOFING, Fig. 5158.

Span of roof ... ... feet	15	20	25	30	35
Price of each truss	£2 3 0	£3 3 6	£4 4 6	£5 0 0	£7 5 0
Weight ,, ... lbs.	224	350	476	546	812
Covering per foot run of roof, 24 gauge	8/9	11/3	13/3	15/8	18/9
,, ,, ,, 22 ,,	10/3	12/3	14/10	17/-	21/3
,, ,, ,, 20 ,,	11/7	14/3	17/-	19/9	24/-
,, ,, ,, 18 ,,	13/1	16/8	19/7	23/-	27/3
Span of roof ... ... feet	40	45	50	55	60
Price of each truss	£8 9 0	£10 14	£12 7	£15 1 6	£18 2
Weight ,, ... lbs.	952	1232	1456	1736	2028
Covering per foot run of roof, 24 gauge	22/-	24/4	27/-	30/-	32/9
,, ,, ,, 22 ,,	24/6	26/3	30/-	33/1	36/3
,, ,, ,, 20 ,,	29/3	29/6	35/-	38/1	42/-
,, ,, ,, 18 ,,	33/9	35/-	40/8	44/6	50,6

MATERIALS FOR CURVED IRON ROOFS.—The following approximate estimates are made on the same basis as those for ridge roofs, the trusses being 10 to 12 feet apart and complete with L steel purlins. If timber purlins are provided by the purchaser, the cost is proportionately reduced, but steel is usually preferable.

For cost of packing, delivery, &c see page 217.

PRICES OF CURVED CORRUGATED ROOFING, Fig. 5159.

Span of roof ... ... feet	15	20	25	30	35
Price of each truss	£1 1 0	£1 7 6	£2 16 6	£3 6 0	£4 16 0
Weight ,, ... lbs.	105	140	315	378	540
Covering per foot run of roof, 24 gauge	8/3	10/9	13/-	15/7	18/9
,, ,, ,, 22 ,,	9/6	11/9	14/7	17/2	21/3
,, ,, ,, 20 ,,	10/10	13/8	16/9	19/10	24/3
,, ,, ,, 18 ,,	12/4	16/1	19/4	23/3	27/6
Span of roof ... ... feet	40	45	50	55	60
Price of each truss	£6 1 6	£8 12 6	£10 17 0	£14 15 0	£17 3 0
Weight ,, ,, ... lbs.	720	986	1250	1970	2100
Covering per foot run of roof, 24 gauge	22/-	24/4	27/-	30/-	32/9
,, ,, ,, 22 ,,	24/8	26/3	30/2	33/3	36/3
,, ,, ,, 20 ,,	29/7	29/9	35/3	38/3	42/-
,, ,, ,, 18 ,,	34/-	35/6	41/6	44/9	50/6

MATERIALS FOR IRON BUILDINGS.—The following prices of materials, with the weights of sheets of the gauges and lengths ordinarily used, furnish the data required for estimating the cost of such materials to be attached to timber or iron work provided by the purchaser.

Corrugated galvanised iron.—Each sheet covers a net width of 2-ft. exclusive of side laps, and any of the sizes mentioned can usually be supplied for 16/6 to 17/- per cwt.

WEIGHTS OF GALVANISED CORRUGATED SHEETS.

Length of sheet ... ... feet	5	6	7	8	9
Weight of ,, 24 gauge ... lbs.	$14\frac{3}{4}$	$17\frac{1}{2}$	21	24	27
,, ,, 22 ,, ... ,,	$17\frac{1}{2}$	21	$24\frac{1}{2}$	28	$31\frac{1}{2}$
,, ,, 20 ,, ... ,,	$21\frac{1}{2}$	26	30	$34\frac{1}{2}$	39
,, ,, 18 ,, ... ,,	27	32	$37\frac{1}{2}$	$42\frac{3}{4}$	48

Galvanised bolts and nuts for joining sheets, cost 4d. per dozen.

Galvanised screws for fixing sheets to wood, cost $3\frac{1}{2}$d. to 4d. per dozen.

Galvanised capping for the apex of ridge roofs, costs 6d. per foot rim.

Ventilators for curved roofs cost about 18/- each and are usually fixed about 10 feet apart.

Galvanised wrought iron eaves gutters cost about 7d. to $8\frac{1}{2}$d. per foot.

Cast iron down pipes, painted, cost about 6d. per foot.

CAST IRON COLUMNS.—The sections and weights of these vary considerably, but the average cost of columns suitable for sheds or warehouses from 25 to 60 feet span—at per foot run of building—will be found at page 218.

STEEL COLUMNS, being (practically) unbreakable, are frequently preferred for shipment or long transit. The lower end is provided with a cast iron base, so that little or no masonry or other foundation is required.

PRICES OF STEEL COLUMNS.

Height of columns from floor to eaves ... ... feet	16	18	20
Price of columns ... ... each	23/-	50/-	58/-

For painting, delivery, etc. of these and other materials for iron buildings see page 217.

GRAIN ELEVATORS.

PORTABLE GRAIN ELEVATORS are made of all capacities from 20 to 100 tons per hour (or more) for raising grain, seed, &c. from the hold of the vessel of any depth, and delivering it into store, or into barge alongside, or for weighing and delivering it either into sack or overside.

The elevator casing is usually 29 feet high, with telescopic legs to reach a depth of 40 feet, but these proportions are altered to any extent required to suit the dimensions of vessels and the mode of delivery.

If the grain must be weighed on deck, the height above the combings is increased sufficiently to deliver the grain into the hopper, so that an elevator 29 feet long will not discharge a ship more than 34 feet deep, but—as already indicated—the lengths can be increased to adapt the elevator for the work to be performed.

The telescopic legs automatically descend as the grain is discharged, and admit of grain being raised from both sides of the screw tunnel simultaneously, or for raising grain continuously if there is a "list" to either side.

The elevator plant, engine, boiler, etc. are usually carried on a barge provided for that purpose, the elevator gear, and engine to drive it, being lifted on board by the ship's tackle.

Information required.—(1) The maximum and minimum dimensions of the ships to be discharged, or cross section showing the depth from top of hatchway to bottom of hold and the dimensions and position of screw tunnels. (2) Dimensions of largest and smallest hatchways of vessels to be discharged. (3) Whether the grain is to be delivered on quay, or overside, with or without weighing, or what combination of these operations is desired. (4) Whether the installation is to be complete with boiler and accessories, to supply steam from barge.

The cost of a portable elevator to raise 20 tons of grain per hour with single telescopic leg to reach to a depth of 25 feet from the top of the combings and discharge into weighing machine for delivery overside or into sack on deck, with the necessary detachable chain and gear for transmitting power to the elevator, portable band conveyor and swivel driving apparatus, engine of ample power, and beams to support the elevator on the combings is about £400

The approximate weight of the heaviest piece is about 29 cwt.

The cost of a portable elevator to raise 60 tons per hour, with double telescopic legs to reach to a depth of 40 feet and portable band conveyors to deliver the grain into store at distances up to 80 feet, or into barge on either side, without weighing, and complete with double cylinder engine, etc. is about £550

The approximate weight of the heaviest piece is 39 cwt.

The cost of packing for shipment and delivery f.o.b. is about 5 per cent.

The price of a vertical cross-tube boiler to supply steam to the engine, complete with fittings including injector, dial steam pressure gauge, and double safety valve is about .. £85.

PNEUMATIC GRAIN DISCHARGING MACHINERY.—The advantages claimed for this system are :

1. Improvement in the grain by intimate contact with the conveying air.
2. The facility for reaching any part of the hold and conveying the grain through tortuous pipes for delivery overside or into store.
3. Entire absence of danger to life or limb.
4. Low cost of working, no labour in trimming being required. The saving in this item alone is often equal to the whole cost of discharging.

The machinery is usually afloat and is available for use in any part of the dock, harbour, or river. It consists principally of a set of steam driven air-exhausting pumps, with the necessary boiler, power and connections, the necessary suction and delivery pipes, and towers supporting automatic air-locks through which the grain is delivered to a weighing machine, from which it passes direct into craft alongside, or into sacks as desired. Arrangements can also be provided for delivering at any point on the top, or other floor of the grain store, all operations being carried on automatically.

Working capacity.—There is scarcely a limit to the quantity of work for which machinery of this kind can be constructed but, as a rule, large plants are more economical than small ones.

Information required.—Full details should be given with regard to the kinds and maximum quantity of grain or seed to be handled in a given time, and the distances, horizontally and vertically, through which it is to be conveyed.

GRAIN CONVEYORS, ELEVATORS, Etc. are referred to at pages 224 and 225.

GRAIN STORAGE TANKS.—Air-tight and vermin-proof cylindrical steel tanks have been largely and sucessfully used in the United States; the storage capacity of each tank being about 110,300 bushels.

The dimensions of the tanks are usually about 51½-ft. diameter and the height 66-ft. The roof is dome shaped and provided with man-holes for filling the tank and for other purposes. The floor is flat and is fitted with openings with sliding doors to regulate the rate of discharge.

Filling and emptying.—The grain is brought over the top of the tank by a belt conveyor to fill the tank, a similar belt below the floor serving to transfer the grain, which is discharged through the bottom openings, to the railway wagons.

ELEVATORS AND CONVEYORS.

BUCKET ELEVATORS (as distinguished from ladder and bucket dredgers, which are referred to elsewhere) are formed of a series of buckets fixed on an endless leather or cotton belt, or on a detachable link chain, which can be lengthened or shortened at pleasure, for raising grain, coal, ore, clay, and other materials, wet or dry.

Belt elevators are carried on turned pulleys at each end, the uppermost being the driven pulley, as are commonly used in connection with grain elevators, flour mills, and other industries.

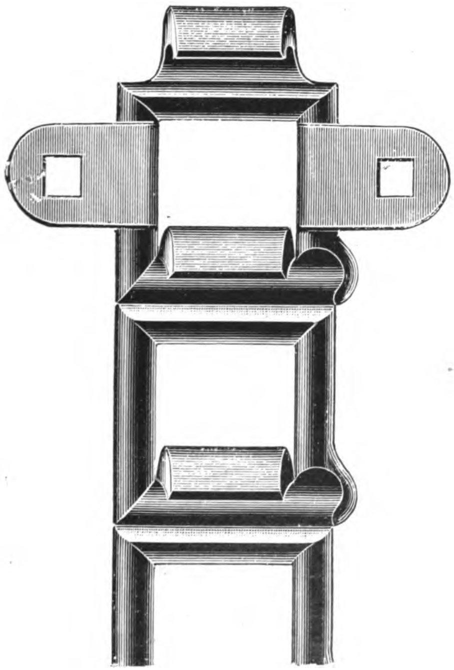


Fig. 5160.

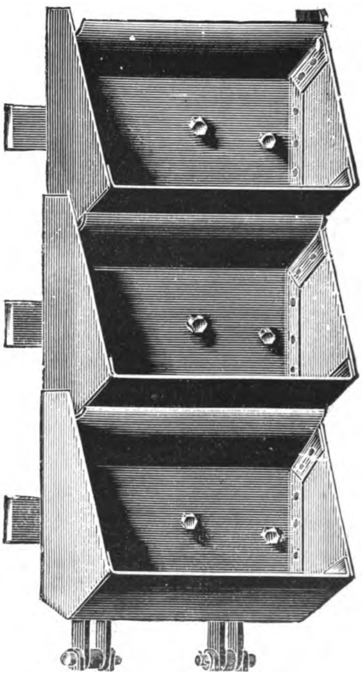


Fig. 5161.

Chain elevators.—Fig. 5161 represents one of the usual forms of the well-known steel, or malleable iron, detachable link chain belt driven by sprocket wheel, and is usually quite satisfactory, although a belt formed of long or short linked pitch chain may, in some cases, be preferable.

The advantages of the chain elevator are that it is unaffected by temperature or moisture and cannot slip even when running slack and at slow speed; it is also very much more durable than a leather belt when raising gritty materials, although with a properly designed elevator either type can be largely protected when working under the last-named conditions.

The buckets and chains are made of any desired dimensions, shape and strength, with bodies solid or perforated as required for dry or wet materials. The front lip is of the same section as the body or strengthened by a steel band. For hard materials it is made either shovel shape, or serrated to draw in matter which does not flow freely. Steel tines are used for materials of more compact character.

Seamless steel buckets represented by Figs. 5160 and 5161 are formed by hydraulic pressure from mild steel plates of dimensions and strength suitable for the use to which they will be put, and of capacities varying from 15 to 1000 cubic inches; those of larger capacities, or of exceptional shape or section, are made of two or more plates and rivetted up.

The prices of seamless steel buckets range from about 5d. to 30/- each.

Detachable link chain belt, a usual form of which is shown in Fig. 5160, is made in malleable cast iron or in crucible steel. The former costs rather less but is not so durable or quite so reliable as steel.

The prices of steel chain range from about 8d. to 5/- per foot.

Sprocket wheels for driving detachable link chain are usually made of cast iron, and can be obtained in all dimensions from 4 inches to 4 feet diameter, the pitch of teeth being arranged to suit the chain. When ordering these wheels it should be indicated which of them is driven and which is the driver.

The prices of sprocket wheels, bored to Whitworth gauge (or template) and key seated, range from 2/6 to about £5 each.

BELT AND CREEPER CONVEYORS.—The number of purposes for which conveyors and elevators of these types are profitably employed in transferring and discharging materials of all sorts, from grain or flour to masses of rock or other matter—wet or dry—are practically unlimited, and so are the ingenious appliances which have been (and can be) devised to fulfil almost any conceivable conditions.

The driving power is small, the belt occupies very limited floor space, and any length of traverse in a straight line or at an angle—horizontally or on an incline—can be provided for by one or other of the systems referred to. The space at disposal does not admit of adequate illustration even of the combinations in common use, but the following brief notes may be of some service in determining the arrangement best adapted for the purpose which may be under consideration.

BELT CONVEYORS, whether of leather, vulcanized rubber, or textile fabric—so well known in connection with the transfer of grain, plastic materials, ore, etc. through long distances—can usually be arranged to discharge anywhere in the length of traverse, or to deliver on to other belts which carry the load in any direction desired.

PLATE AND LINK CONVEYORS are constructed of any dimension desired for carrying heavy packages, stone, ore, and other substances for which an ordinary belt would be unsuitable.

These conveyors are formed of a series of steel plates or wood slabs (or a combination of them) secured to iron or steel links of suitable length and section to constitute an endless flexible travelling table which can easily be lengthened or shortened, as occasion requires.

The tables are supported by rollers where necessary, and arrangements can usually be made for discharging automatically where desired. The driving power may be at either end, but conveyors working on an incline should be driven at the upper end.

Plate and link conveyors effect important savings in the time and cost of handling merchandise and materials; the saving in the cost of labour alone frequently amounts to 10 to 25 per cent. per annum on the price of the plant.

TRAY CONVEYORS.—The arrangements of parts is similar to that last described, but the table has sides—trough form—of the height required for carrying materials liable to roll off a flat surface.

If necessary these conveyors may be fixed at any angle up to about 25°.

PUSH PLATE CONVEYORS.—Another modification of the endless table type of conveyor is obtained by fixing plates across the table at intervals, suitable for preventing coal, ore, etc from scattering when traversing on an ascending incline. The tables are flat or trough shaped, and open or completely enclosed to suit the articles to be carried.

JIGGER CONVEYORS.—This simple and useful arrangement consists of a steel trough of any desired section or length, with light spring supports at intervals, and a crank with the fittings and connections required to produce a vibrating motion throughout the length of the trough; this gear is fixed under the trough, where convenient, and requires little driving power. The apparatus may be open or enclosed, and materials fed in at one end of the trough propelled forward by the vibrations imparted by the revolutions of the crank; the speed at which the materials travel is regulated by the speed at which the crank shaft is driven. A 12-inch trough will pass 10 tons of ore per hour on the level or at a slight upward incline.

DRYING OR STOVING CONVEYORS.—A jigger of the last-mentioned type fixed in a heated chamber, will dry or bake matter during its passage through the chamber. A similar result is obtained by constructing the trough with a jacket to which steam or hot air is admitted, the speed of progression—in both cases—being regulated to give the desired exposure to heat.

SPIRAL CONVEYORS, so largely used for carrying grain, flour, and many other products, consist of a trough provided with bearings and central shaft to which the spiral blades are secured and arranged to deliver to right or left as desired.

The troughs are made of sheet steel or cast iron and the blades of rolled steel plate of the section necessary for the nature and quantity of materials to be dealt with; the blades are formed by hydraulic pressure and of all sizes from 4-in. to 4-ft. diameter.

The following approximate prices for current sizes of these conveyors suitable for handling granular matter, sugar, small coal, etc. may be useful for reference.

The prices are for conveyors of a minimum length of 6 feet, shorter lengths being charged as 6 feet long.

PRICES OF SPIRAL COIL CONVEYORS.

Diameter of spiral coil ... inches	6	8	10	12	15	18	20
Approximate capacity per hour, tons	3	6	9	15	22	33	45
Prices of spiral only ... ... per ft.	1/3	2/-	3/-	4/6	6/-	7/-	8/-
,, with shaft and bearings ,,	4/-	5/-	7/-	9/6	14/-	18/-	20/-
,, steel troughs ... ... ,,	3/3	4/-	5/3	7/-	9/6	10/6	13/-
,, cast iron ... ... ,,	3/9	5/6	7/9	10/9	13/6	17/-	18/-
,, outlets with slides ... each	8/-	9/6	11/6	15/6	17/6	21/-	24/6

The cost of packing for shipment and delivery f.o.b. is usually about 5 per cent.

CABLE CONVEYORS.—A simple and inexpensive form of conveyor is provided by an endless flexible steel wire rope with discs at intervals running in an iron or timber trough of V, or other suitable section.

The cable is driven from either end and supported where necessary by grooved pulleys, with open space in the rim to clear the discs. The discs carry forward materials such as coal, pulp, refuse and the apparatus is equally efficient whether the matter is wet or dry, but not so if it is sticky.

INCLINE ELEVATORS for carrying fibrous materials are provided with steel forks attached to a pair of endless chains with top driving and bottom carrying pulleys; the frame, sides and charging hopper below are usually in timber. The chain being traversed in an upward direction, the steel forks take their proper charge from the feeding hopper and deliver it freely at the upper end.

VERTICAL ELEVATORS for raising casks, bales, etc. A pair of iron or timber uprights carry the driving gear and a pair of endless chains, with brackets spaced to suit the work. One man only is required to roll the load on to the brackets, the discharge above being usually automatic.

Lifts for small or fragile articles.—The arrangement is similar to that last described, but suspended trays are substituted for the brackets, and the delivery is very rarely automatic.

STEAM TUGS AND LAUNCHES.

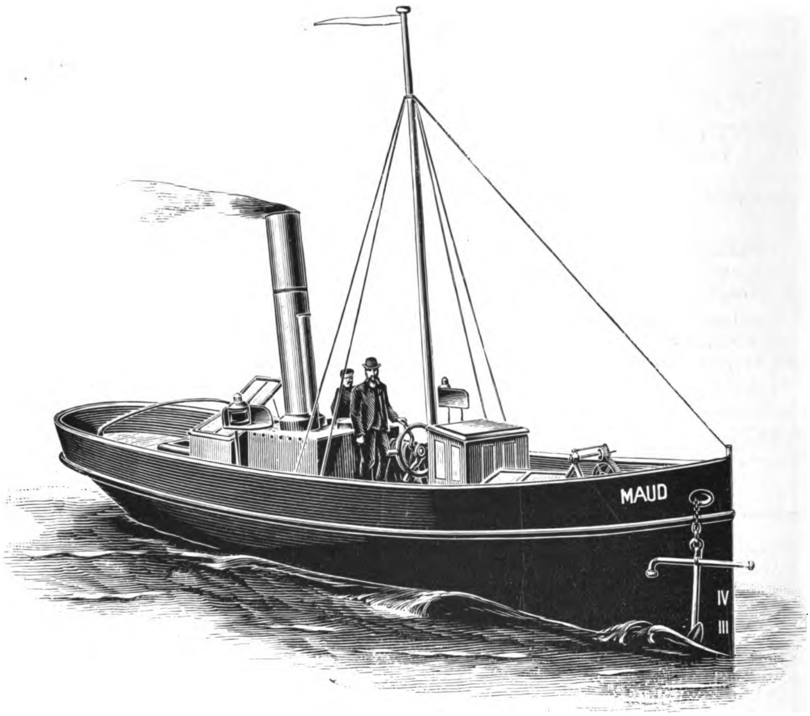


Fig. 5162.

SCREW STEAM TUGS AND CARGO BOATS.—The boat illustrated by Fig. 5162, with compound surface condensing machinery, was designed and built by the writer for use in harbour construction, and subsequently for coast service, carrying cargo, towing, etc.

Other boats of various dimensions, fitted with compound, or with high pressure engines (principally the former) have been delivered in steam or (in some cases) sent out in parts ready for erection at destination, as described further on.

The engraving represents the boat on its way for delivery at a Continental port.

TUGS WITH HOISTING MACHINERY.—Some of these boats have been fitted with hoisting machinery for working cargo in an open sea way, as well as the appliances for towing barges to and from quay or jetty.

STEAM TUG WITH FRESH WATER TANK.– In other cases large fresh water tanks and a steam pump have been provided for supplying ships' tanks, and satisfactory earnings have been made from this source, in addition, of course, to the towing dues.

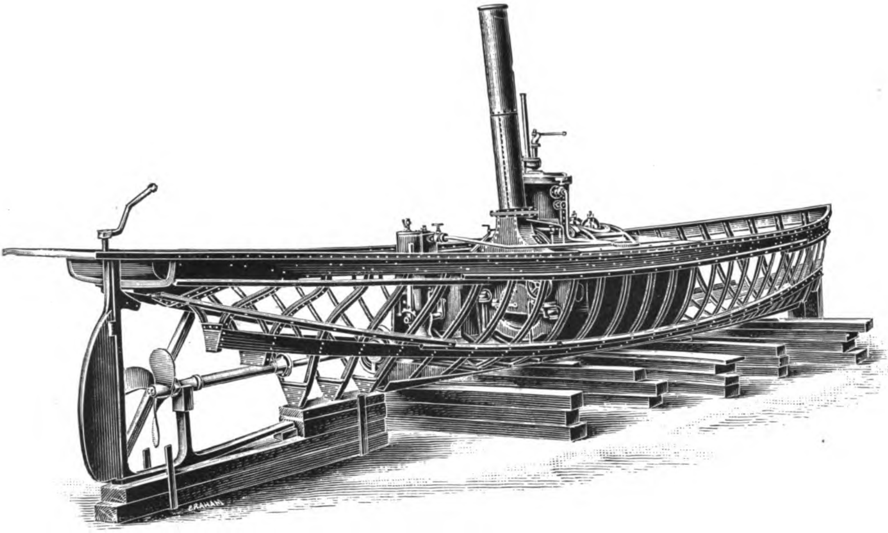


Fig. 5163.

LAUNCHES AND TUGS FOR COMPLETION AT DESTINATION.—Boats of the types Fig. 5162 and 5163 have (for various reasons) been sent out in parts properly marked, and machinery erected in place before shipment.

BOAT IN FRAME.—Fig. 5163 represents a boat for towing and passenger service as it appeared in the writers yard, with all machinery erected in place and the parts carefully marked for re-erection. Further facilities for assembling are afforded by painting the opposite sides different colours, and as a matter of fact the work has been carried out mostly by native labour without trouble either in completion or in subsequent working.

This system has been adopted for boats with steel plating which were sent out ready for rivetting, an ample supply of rivets, service bolts, etc. being also provided. But with few exceptions the sheathing has been of teak or mahogany both of which are strong and durable, do not shrink or warp when exposed to sun, and present a good surface when varnished.

Drawings for all the wood work were sent in advance so that the boat was completed soon after the arrival of the materials shown in the engraving.

It will be understood that there is scarcely a limit to the size of boats built on this system, the stearing gear and such fittings, equipment, etc. as may be required, being provided to suit the wishes of purchasers.

INFORMATION REQUIRED.—A complete specification is, of course, the most satisfactory; if this cannot be supplied, the fullest possible details should be furnished, the undernamed being essential:

Dimensions and type of boat required and nature of service.

Minimum draft of water.

Strength of currents or speed of stream.

Maximum speed for steaming.

Kind and quality of fuel and water available and distance between points of supply.

STERN WHEEL STEAMERS.—Information of the kind last named is required for designing and estimating the cost of steamers of this type, which as is well known, are highly successful where no other mode of propulsion would be possible.

STEAM AND OIL LAUNCHES.

The requirements in regard to size, speed, accommodation, equipments and so forth, are so extremely diversified, that the following information is limited to that relating to the smaller, but generally useful sizes and types of launches which are indispensable in river, harbour and dock service.

The prices are based on the working costs at the time the boats were built or designed, and may not accurately represent those current at other times, so must be regarded as only approximate.

Materials and finish.—In all cases these are in accordance with the British Admiralty regulations, and—as regards materials—it may be well to point out that although pine is quite satisfactory in this and similar climates if kept well painted, it is less suitable than teak or mahogany for use in hot climates, and that the latter give better results in wear and tear, appearance and durability, in any climate.

Speeds.—As a rule, those mentioned suffice for practical and commercial purposes, but there is of course no sort of difficulty in producing launches for such higher speeds as may be required.

OPEN STEAM LAUNCHES CLINCHER BUILT.—The boats are built and engined as above described. The boiler is vertical, of ample power, and is easily cleaned.

Launches with compound machinery.—Unless otherwise agreed the condenser is fixed outside in the usual manner, but it can be fixed inside at a small extra cost.

PRICES OF CLINCHER BUILT OPEN LAUNCHES.

Length of boat ... ... feet	20	22	24	26	28	30
Beam of boat ... ... ,,	5	5	5½	5¾	6	6½
Depth of boat ... ... ,,	34	34	35	37	39	40
Speed, miles per hour ... ... about	7	7	7	8	8½	8½
Price of Launch in Pine, with high pressure machinery	£170	£180	£195	£220	£240	£255
Price of Launch in Teak or Mahogany ...	£187	£198	£215	£240	£265	£280
Price of Launch in Pine, with compound machinery	£225	£237	£245	£285	£308	£330
Price of Launch in Teak or Mahogany ...	£248	£260	£270	£315	£340	£365

STEAM LAUNCHES, CARVEL BUILT, WITH CABIN.—These boats are built and engined for higher speeds than those last referred and the three larger sizes have decking as well as cabin.

PRICES OF CARVEL BUILT STEAM LAUNCHES WITH CABIN.

Length of boat ... ... feet	32	36	40	45	50
Beam ,, ... ,,	6¾	7	7½	8	8½
Depth ,, ... ,,	3½	3¾	4	4¼	4½
Speed, miles per hour ... ... about	10	10	9½	12	11
Price of launch in pine, with high pressure machinery	£325	£358	£435	£660	£700
,, ,, in teak, mahogany or steel ...	£374	£412	£605	£760	£800
,, ,, in pine, with compound machinery	£390	£440	£624	£770	£810
,, ,, in teak, mahogany or steel ...	£448	£505	£715	£885	£930

LAUNCHES WITH OIL ENGINES.—The engines work with the ordinary paraffin (or kerosine) lamp oil, and are ready to start at any time, at a few minutes notice, no attention being required during the run, and no labour or fuel wasted, as in stoking a steam boiler when waiting.

Machinery and accessories.—These consist of a compact oil engine, screw propellor shaft, bronze reversible screw propellor, tank to carry a supply of oil for 8 to 10 hours run, and connections between it and the engine. The consumption of oil is about 1 pint per brake H.P. per hour.

OPEN LAUNCHES WITH OIL ENGINES.—The boats are clincher built and copper fastened, and are fitted with machinery and accessories as above described.

PRICES OF OPEN OIL LAUNCHES.

Length of boat ... ... feet	16	18	20	22	25	26
Beam of boat ... ... ,,	$4\frac{1}{2}$	$4\frac{3}{4}$	$5\frac{1}{4}$	$5\frac{1}{2}$	6	6
Speed, miles per hour ... ... about	$5\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{1}{2}$	6	$6\frac{1}{4}$	$7\frac{1}{2}$
Brake H.P. of engine	2	$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{3}{4}$	$3\frac{3}{4}$	6
Price of launch in Pine...	£150	£169	£187	£193	£218	£303
Price of launch in Teak and Mahogany ...	£158	£180	£193	£200	£227	£310
Approximate weight ... ... cwts.	$8\frac{1}{2}$	14	$16\frac{1}{2}$	17	$19\frac{1}{2}$	24

OIL LAUNCHES WITH CABIN—These are carvel built and fitted with machinery as last described. The cabin is aft, and is complete with windows and plain seats.

If the cabin and engine room are in Teak, the extra cost is £50 to £60.

PRICES OF OIL LAUNCHES WITH CABIN.

Length of boat ... ... feet	30	35	40	45	50
Beam ,, ... ,,	$6\frac{3}{4}$	7	$7\frac{1}{4}$	$7\frac{1}{2}$	8
Speed, miles per hour ... ... about	$7\frac{1}{2}$	7	$7\frac{1}{2}$	$7\frac{1}{2}$	7
Brake horse power of engine	6	6	9	12	12
Price of launch in teak or mahogany ...	£370	£438	£505	£670	£730
,, ,, in steel	£416	£450	£555	£755	£820
Approximate weight ... ... tons	2	$2\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{1}{2}$	5

SEAMLESS STEEL BOATS OR CUTTERS.—The inconvenience and loss caused by the rapid deterioration of timber-built boats, or even of steel boats composed of small plates with a number of seams of rivets, has led to the invention now referred to which completely removes these defects.

The boats are built from 18 feet long to carry 12 men, to 30 feet long to carry 50 men, but only a few useful sizes are tabulated ; other sizes are, however (practically), in the same ratio as regards dimensions and cost.

Materials and construction.—The seamless boat consists of two plates of mild steel, moulded to shape, and rivetted together with a bulb-shaped steel bar between them which forms stern, keel and stern post, so they remain watertight and perfectly serviceable under exposure to heat or weather which is fatal to boats of the ordinary type.

Galvanized iron air-tight tanks at bow and stern insure flotation even if the boat is full of water, and each boat is complete with rudder and rowlocks, hook at each end for lowering, and with gunwale, strakes, seats and bottom boards fitted in the usual manner.

SEAMLESS STEEL LIFEBOATS are built as above described, and are fitted with yellow metal, galvanized iron, wood, copper, or wood fibre tanks, rudder, tiller and life lines, and with Board of Trade outfit, the cost of which is given separately and can be supplied with any of the boats.

Board of Trade outfit.—This comprises ash oars, boat hook, mast and yard, sea anchor, painter, water-breaker, oil distributor, compass, lamp, oil can, tomahawks, and bailer.

PRICES OF SEAMLESS STEEL BOATS OR CUTTERS.

Carrying capacity ... ... men	16	20	26	32	40
Length of boat	20-ft.	22-ft.	24-ft.	26-ft.	26-ft.
Beam of boat	6-ft.	6-ft. 6-in.	6-ft. 8-in.	7-ft. 3-in.	8-ft.
Depth	2-ft. 5-in.	2-ft. 5-in.	2-ft. 9-in.	3-ft.	3-ft. 3-in.
Price of boat as described .. about	£35	£40	£45	£48	£52
Price of lifeboat with yellow metal tanks	£44	£50	£58	£64	£68
Price of Board of Trade outfit .	£6	£7	£7 10	£8	£9

The cost of packing for shipment, so far as necessary, and delivery f.o.b. is usually about 5 per cent.

FLOATING DOCKS.

Although it is impossible in the limited space at disposal to treat this important subject at all exhaustively, attention may be directed to some of the advantages offered by a floating dock over a graving dock built in masonry.

Prominent amongst these are:

- Large choice of site and absence of difficulties in regard to installation, infiltration, &c.
- Low cost (probably one-third to one-half of that for a masonry dock) and very rapid construction.
- The short time occupied in docking.
- Endless variation in size and form to suit local conditions, and great facilities for maintenance.
- A floating dock can be built complete and towed to its destination, or it can be built in the locality where it is to be employed.

The dock may be off-shore and tied to it, or of the the double wall type, and available for use in any position.

In both cases the floor of the dock is usually formed of mild steel water tight pontoons, rectangular in shape, with the necessary bulkheads, stiffeners, &c. and connections to the centrifugal pumps.

The sides are constructed in a similar manner, and are arranged to carry the pumps and machinery for driving them, as well as the bilge blocks, side shores, gear for hauling the ship, cranes for manipulating materials, &c.; ample margin is provided for freeboard when sinking for docking, and in pumping power for discharging the water ballast used for that purpose.

In addition to some advantages in lightness of construction in off-shore docks, the facility for sheering sideway on to the dock, instead of swinging across, as required in entering an ordinary graving dock, is sometimes an important consideration.

Electric equipment.—Probably electric power transmitted from shore will be more extensively used in the future than it has been hitherto. This saves the weight of boilers, water, fuel, etc. for working the pumps, cranes and other machinery, and practically all operations can be controlled from one point.

FLOATING PONTOON DOCK.—The following description relates to a dock of the double wall type which was built for a continental power, and was towed to its destination after completion in this country, affording an excellent example of facility for transport.

Dimensions.—The dock is constructed to lift a vessel weighing 13000 tons. The length is 450-feet between perpendiculars, the breadth of pontoons is 117-feet, and their depth 13-feet 6-inches, each pontoon being divided into ten water-tight compartments.

Arrangement of machinery.—The engines, boilers, centrifugal and donkey pumps are fixed in towers on each side of the pontoon, and each watertight compartment is connected with the centrifugal pumps which are capable of discharging 11·500 tons of water per hour against a head of 88-feet.

Very useful features in this dock are exceptionally convenient arrangements of bilge blocks. and of appliances for mooring, speaking tubes between all departments, and facilities for disconnecting and docking, on the pontoon itself, any portion of the dock which may require repair or painting.

ELECTRIC LIGHTING INSTALLATION.—It may be mentioned incidentally that this was provided, with search lights and all appliances necessary for working throughout the 24 hours.

PUMPING MACHINERY FOR FLOATING DOCKS is referred to in Section III. (Pumping Machinery).

FLOATING DOCKS BUILT IN TIMBER.—Examples are given at pages 80 and 81 of Section III. of this Handbook of pumps and engines for floating docks, some of which have been required for comparatively temporary purposes, but all were built of timber at, or near to, their destination, the engines and mechanical portions being sent out ready for erection.

The accommodation required was obtained with a small capital outlay, and one of the docks which was built and equipped for permanent service has been a great financial success.

CHAINS AND ROPES.

CRANE CHAINS AND SLINGS.—Seeing that failures of lifting chains and slings cause so much loss by damage, as well as risk to life and limb, it is singular that so little attention is paid to the quality of iron from which the chains are made or to their maintenance in good condition ; indeed it is far from unusual to have a link put into a chain or sling by a smith unaccustomed to such work, and straightway used without the further examination or test which ought always to be made.

Tests of chains.—The chains and chain slings referred to in the following tables are made of special chain iron and the approximate prices include the cost of testing to 10 per cent. beyond Admiralty proof strain.

Lloyd's Test.—If a certificate of Lloyd's test is required the extra cost varies from 3/- to 1/6 per cwt. but the charge to cover the fee paid for testing, carriage to and from the test house, etc. is uusally about 2/- per cwt.

Annealing and examination of chains.—A precaution rarely taken, but of far greater importance than is generally recognised, is that of periodically inspecting, annealing and testing all lifting chains and chain slings.

The links of chains in constant use must necessarily be strained alternately in opposite directions and this (especially with chains working at high speed) leads to unperceived deterioration which may make them positively dangerous, even when carrying comparatively light loads.

Annealing usually restores elasticity, but even this ought not to be relied upon without, in addition, careful examination and test.

Maintenance of chains and ropes.—Both chains and ropes should, as far as possible, be kept free from grit and dirt and those used for coiling, as in lifting, etc. should be properly lubricated.

SHORT LINK CHAIN, PROOF AND WORKING STRAINS, WEIGHTS AND PRICES.

			Special Treble Best Quality.			Best Best Quality.		
Size.	Proof Strain.	Weight Per Foot.	Working Load.	Breaking Weight	Price Per Foot.	Working Load.	Breaking Weight.	Price Per Foot.
ins.	tons.	lbs.	tons.	tons.	s. d.	tons.	tons.	s. d.
3/16	.40	.50	.20	.87	4¾	.20	.8	3¾
¼	.75	.75	.40	1.75	4½	.30	1.6	4¼
5/16	1.12	1.25	.60	2.75	5¾	.50	2.5	5½
⅜	1.62	1.66	.90	3.62	6¾	.70	3.5	6¼
7/16	2.25	2.25	1.2	5.5	8½	1.00	5.2	8
½	3.00	2.91	1.5	7.25	10	1.3	7.2	9½
9/16	3.75	3.66	1.9	9.0	1 0	1.7	8.5	11½
⅝	4.62	4.50	2.4	11.25	1 2	2.1	11.0	1 1¼
11/16	5.62	5.25	2.9	13.5	1 4¼	2.5	13.0	1 3¼
¾	6.75	6.16	3.5	16.0	1 6½	3.0	15.5	1 5½
13/16	7.90	7.16	4.1	19.0	1 9	3.6	18.0	1 7½
⅞	9.12	8.5	4.8	22.0	2 0	4.2	21.0	1 10½
15/16	10.5	9.5	5.5	25.0	2 1¾	4.8	24.0	2 1
1	12.0	11.0	6.2	28.0	2 5¾	5.4	27.0	2 4½
1 1/16	13.5	12.26	7.0	31.5	2 8¾	6.2	30.0	2 7
1⅛	15.12	13.66	7.9	35.0	3 0	6.9	33.0	2 10¼
1¼	18.75	16.0	9.7	43.0	3 6½	8.5	41.0	3 4¼
1⅜	22.62	19.6	11.8	52.0	4 4	10.3	51.0	4 1½
1½	27.00	23.3	14.0	62.0	5 2	12.3	61.0	4 10¾

LIFTING POWER OF BLOCKS.—The following table gives the **test** load for pulley blocks, but the **working** load should not exceed about half the test load. A sheave 9 inches diameter carries a test load of 35 cwt. and, if 2 and 3 sheave blocks are used, we have 5 parts × 35 = 175 cwt. or 8¾ tons ; the safe working load, therefore, is about 4¼ tons.

POWERS OF BLOCKS.

Diameter of sheave...inches	5	6	7	8	9	10	11	12	14	16
Test load each sheave cwts.	10	12	18	27	35	48	60	75	90	120

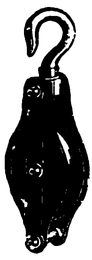


Fig. 5173.

Fig. 5174.

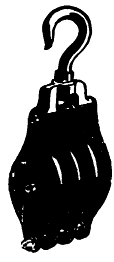


Fig. 5175.

Fig. 5176.

PULLEY BLOCKS "London pattern," Fig. 5173 to 5176.—The side plates and strengthening strips are of mild steel and the crosshead and hook are wrought iron forgings. Blocks with sheaves exceeding 9 inches diameter have swivelling loops. The cost with fixed loops is much lower.

The size of crane chain each block will take is given below; the width of the groove ndicates the diameter of rope to be used.

PRICES OF PULLEY BLOCKS **(Iron Sheaves)** Fig. 5173 to 5176.

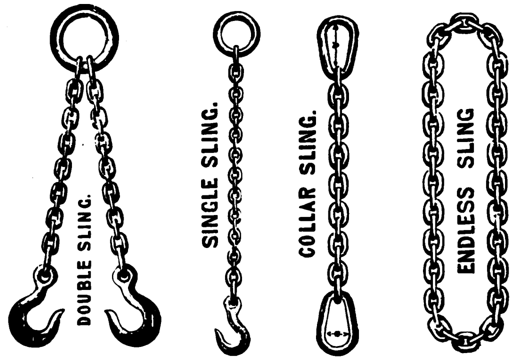
Diameter of sheave ... inch	5	6	7	8	9	10	11	12	14	16
Width of groove ... ,,	7/8	1	1¼	1½	1¾	2	2¼	2½	2¾	3¼
Size of chain... ... ,,	¼	5/16	3/8	7/16	½	9/16	5/8	11/16	¾	7/8
Price, 1 sheave, Fig. 2324...	6/6	7/6	9/6	12/6	20/-	30/-	45/-	60/-	80/-	115/-
,, 2 ,, Fig. 2325...	9/6	11/-	16/-	22/6	32/-	50/-	90/-	105/-	126/-	175/-
,, 3 ,, Fig. 2326...	13/6	14/6	21/-	30/-	45/-	70/-	115/-	140/-	170/-	240/-
,, 4 ,, ...	17/3	20/-	30/-	42/6	65/-	95/-	140/-	165/-	200/-	300/-
,, Snatch block, Fig. 2327	7/6	9/-	11/-	14/-	21/6	42/-	50/-	75/-	95/-	145/-

GALVANISED BLOCKS cost about 30 per cent. more than those above given.

Pulley Blocks with brass sheaves but otherwise as above described and to carry the same working load as blocks with iron sheaves.

PRICES OF BLOCKS, Fig. 5173 to 5176, WITH BRASS SHEAVES.

Diameter of sheave ... inch.	5	6	7	8	9	10	11	12	14	16
Price, 1 sheave, Fig. 2324	10/3	13/6	15/9	21/9	34/9	56/-	78/-	96/-	146/-	255/-
,, 2 ,, Fig. 2325	17/-	21/-	28/9	41/-	61/6	102/-	150/-	188/-	286/-	470/-
,, 3 ,, Fig. 2326	23/9	29/6	39/9	57/9	89/3	148/-	208/-	266/-	415/-	685/-
,, 4 ,, ...	32/3	40/-	55/-	79/6	124/-	199/-	296/-	382/-	620/-	960/-
,, Snatch block, Fig. 2327	11/3	14/-	17/3	23/3	36/3	68/-	90/-	122/-	170/-	263/-



CHAIN SLINGS.—The chains are made of "best best" iron, the hooks and rings are of special quality, and all are tested to full Admiralty proof strain as stated at page .

The lengths specified are lengths of chain, exclusive of hooks or rings.

The double slings are exactly equal in length, and all the prices are for the slings complete, ready for use.

For prices of slings of intermediate or greater length, add at the rate per foot for the size of chain required.

Slings of larger size of chain are made if required.

PRICES OF DOUBLE CHAIN SLINGS.

Size of Chain ... inch	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$
Price of sling 3 feet	6/6	8/-	10/6	14/-	17/3	21/-	24/6
,, ,, 5 ,, ...	8/10	10/6	13/6	17/4	20/11	25 8	27.-
,, ,, 7 ,, ...	11/2	13/-	16/6	20/8	24/7	30 4	34/6
,, ,, 10 ,, ...	14/8	16/9	21/-	25/8	30/1	37/4	42/-
Extra length ... ... per foot	1/2	1/4	1/6	1/8	1/10	2/4	2/6

Size of chain ... ... inch	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
Price of sling 3 feet	29/9	34/6	38/3	48/3	67/3	91/-	125/6
,, ,, 5 ,, ...	35/9	41/6	46/3	58/3	80/3	107/-	143/6
,, ,, 7 ,, ...	41/9	48/6	54/3	68/3	93/3	123/-	161/6
,, ,, 10 ,, ...	50/9	59/-	66/3	83/3	112/9	147/-	188/6
Extra length ... ... per foot	3/-	3/6	4/-	5/-	6/6	8/-	9/-

PRICES OF SINGLE OR LASHING CHAIN SLINGS.

Size of chain ... ... inch	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$
Price of sling, 3 feet	3/3	4/-	5/3	7/-	8/7	10/10	12/9
,, ,, 5 ,, ...	4/5	5/4	6/9	8/8	10/5	13/2	15/3
,, ,, 8 ,, ...	6/2	7/4	9/-	11/2	13/2	16/8	19/-
,, ,, 12 ,, ...	8/6	10/-	12/-	14/6	16/10	21/4	24/-
Extra length ... ... per foot	7d.	8d.	9d.	10d.	11d.	1/2	1/3

Size of chain ... ... inch	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
Price of sling, 3 feet	16/-	18/3	21/-	27/6	37/9	50/-	61/6
,, ,, 5 ,, ...	19/-	21/9	25/-	32/6	44/3	58/-	70/6
,, ,, 8 ,, ...	23/6	27/-	31/-	40/-	54/-	70/-	84/-
,, ,, 12 ,, ...	29/6	34/-	39/-	50/-	67/-	86/-	102/-
Extra length ... ... per foot	1/6	1/9	2/-	2/6	3/3	4/-	4/6

Prices of Collar or Slip Chain Slings.

Size of chain ... ... inch	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$
Price of sling, 3 feet	2/6	3/-	3/7	4/2	5/-	5/6	6/6
,, ,, 5 ,, ...	3/8	4/4	5/1	5/10	6/10	7/10	9/-
,, ,, 8 ,, ...	5/5	6/4	7/4	8/4	9/7	11/4	12/9
,, ,, 12 ,, ...	7/9	9/-	10/4	11/8	13/3	16/-	17/9
Extra length ... ... per foot	7d.	8d.	9d.	10d.	11d.	1/2	1/3
Size of chain ... ... inch	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
Price of sling, 3 feet	8/-	9/6	11/9	17/6	21/-	28/	33/3
,, ,, 5 ,, ...	11/	13/	15/9	22/6	27/6	36/	42/3
,, ,, 8 ,, ...	15/6	18/3	21/9	30/	37/3	48/	55/9
,, ,, 12 ,, ...	21/6	25/3	29/9	40/	50/3	64/	73/9
Extra length ... ... per foot	1/6	1/9	2/-	2/6	3/3	4/-	4/6

Prices of Endless Chain Slings.

Size of chain ... ... inch	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$
Price of sling, 6 feet	4/6	5/-	5/10	6/8	7/8	9/-	10/-
,, ,, 8 ,, ...	5/8	6/4	7/4	8/4	10/6	11/4	12/6
,, ,, 10 ,, ...	6/10	7/8	8/10	10/-	12/4	13/8	15/-
,, ,, 12 ,, ...	8/-	9/-	10/4	11/8	14/2	16/-	17/6
Extra length ... .. per foot	7d.	8d.	9d.	10d.	11d.	1/2	1/3
Size of chain ... ... inch	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
Price of sling, 6 feet	12/-	13/10	16/-	20/-	25/6	31/3	35/-
,, ,, 8 ,, ...	15/6	17/4	20/-	25/-	32/-	39/3	44/-
,, ,, 10 ,, ...	18/-	20/10	24/-	30/-	38/6	47/3	53/-
,, ,, 12 ,, ...	19/6	24/4	28/-	35/-	45/-	55/3	62/-
Extra length ... ... per foot	1/6	1/9	2/-	2/6	3/3	4/-	4/6

STEEL WIRE ROPES.—The kind of rope to be used depends on the service for which it is required. Cheap ropes, which would be quite unsuitable for lifting purposes demanding maximum strength in limited weight and great flexibility, may be quite well adapted for withstanding friction, where flexibility is of no importance ; but with wire ropes—as with most other things—the best is almost always the most economical.

Winding and crane ropes should be made of best flexible steel wire, the strands—each with hemp core—being wound around a central hemp core. The strength and durability of a rope are due to the quality and homogeneity of the steel used and, to ensure these conditions, each wire of each strand is tested to a high tensile strain in the process of manufacture.

Testing wire ropes.—Each wire having been tested during the process of manufacture, a final test—such as that applied to chains—is unnecessary and undesirable. Testing the finished rope stretches it unduly and the margin between "breaking strain" and "working load," as given in the following tables, provides an ample factor of safety.

WINDING AND HAULING ROPES.—The size of rope recommended for a given weight lifted vertically, will serve for determining (by the usual formula) the size of rope to be used for the gradient, weight and speed of haulage for which it is to be employed.

Drums and pulleys for wire rope.—It will scarcely be necessary to point out that the diameters of drums and pulleys should be as large as can conveniently be used, and that very sharp turns in the direction of travel should be avoided as far as possible ; it will be found that if these details are attended to, the life of the rope will be considerably enhanced.

Lubricant for wire ropes.—Winding and crane ropes should be thoroughly well lubricated with a compound of pure vegetable oil and plumbago, when the rope is quite dry and before it is put into use.

Inspection of ropes.—Careful inspection, from time to time, to ascertain the condition of the wires in the strands is strongly recommended.

WEIGHTS AND BREAKING STRAINS OF STEEL WIRE ROPE, WHITE MANILLA, TARRED MANILLA, AND WHITE RUSSIAN HEMP ROPE.

Diam.	Circumference	Steel Wire Rope suitable for Cranes and Winding.		Steel Wire Rope suitable for Mine Haulage and Winding.		White Manilla Rope.		Tarred Manilla Rope.		White Russian Hemp Rope.	
		Breaking Strain	Weight per yard	Breaking Strain	Weight per yard	Breaking Strain	Weight per yard	Breaking Strain	Weight per yard	Breaking Strain	Weight per yard
inches.	inches.	tons.	lbs.	tons.	lbs.	tons	lbs.	tons	lbs.	tons	lbs.
·371	$1\frac{1}{8}$	5	$\frac{7}{8}$	$3\frac{1}{2}$	$\frac{5}{8}$	...	..	...	...	...	..
·413	$1\frac{1}{4}$	...	...	$4\frac{1}{2}$	$\frac{7}{8}$	...	...	...		...	...
·454	$1\frac{3}{8}$	$7\frac{1}{2}$	$1\frac{1}{8}$	$6\frac{1}{2}$	$1\frac{1}{8}$	...	...	...	...	...	...
·495	$1\frac{1}{2}$	$8\frac{1}{2}$	$1\frac{1}{4}$	$7\frac{1}{2}$	$1\frac{1}{4}$	$\frac{4}{5}$	$\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{10}$	$\frac{13}{20}$	$1\frac{1}{4}$
·537	$1\frac{5}{8}$	10	$1\frac{3}{8}$	$8\frac{1}{2}$	$1\frac{3}{8}$	...	...	...	...	..	..
·578	$1\frac{3}{4}$	11	$1\frac{1}{2}$	9	$1\frac{1}{2}$	$1\frac{3}{20}$	$\frac{1}{3}$	$1\frac{1}{12}$	$\frac{2}{5}$	$\frac{19}{20}$	$\frac{1}{3}$
·619	$1\frac{7}{8}$	13	$1\frac{3}{4}$	11	$1\frac{3}{4}$	...	...	...	...	...	...
·660	2	14	$1\frac{9}{10}$	12	$1\frac{9}{10}$	$1\frac{1}{4}$	$\frac{2}{5}$	$1\frac{1}{7}$	$\frac{1}{2}$	1	$\frac{7}{16}$
·702	$2\frac{1}{8}$	15	2	...	...	...	..	...	...	...	...
·743	$2\frac{1}{4}$	16	$2\frac{1}{8}$	14	$2\frac{1}{8}$	$1\frac{4}{5}$	$\frac{11}{20}$	$1\frac{3}{4}$	$\frac{11}{20}$	$1\frac{1}{2}$	$\frac{11}{20}$
·786	$2\frac{3}{8}$	18	$2\frac{1}{2}$	15	$2\frac{1}{2}$	...	...	...	...	..	...
·826	$2\frac{1}{2}$	19	$2\frac{3}{4}$	16	$2\frac{3}{4}$	$2\frac{1}{4}$	$\frac{3}{5}$	$2\frac{1}{10}$	$\frac{4}{5}$	$1\frac{11}{13}$	$\frac{3}{5}$
·867	$2\frac{5}{8}$	22	$3\frac{1}{8}$	19	$3\frac{1}{8}$	...	...	...	...	...	...
·908	$2\frac{3}{4}$	23	$3\frac{1}{2}$	20	$3\frac{1}{2}$	$2\frac{5}{8}$	$\frac{3}{4}$	$2\frac{2}{5}$	$\frac{9}{10}$	$2\frac{1}{12}$	$\frac{3}{4}$
·949	$2\frac{7}{8}$	27	$3\frac{3}{4}$	23	$3\frac{3}{4}$	...	...	...	...	..	...
·990	3	30	4	25	4	$3\frac{1}{5}$	$\frac{9}{10}$	3	$1\frac{1}{8}$	$2\frac{1}{2}$	$\frac{9}{10}$
1·031	$3\frac{1}{8}$	33	$4\frac{1}{4}$	27	$4\frac{1}{4}$	...	...	...	...	...	...
1·074	$3\frac{1}{4}$	36	$4\frac{3}{4}$	30	$4\frac{3}{4}$	$3\frac{9}{10}$	$1\frac{1}{20}$	$3\frac{3}{5}$	$1\frac{3}{10}$	$3\frac{1}{10}$	1
1·114	$3\frac{3}{8}$	38	$5\frac{1}{4}$	32	$5\frac{1}{4}$	...	...	...	...	..	...
1·156	$3\frac{1}{2}$	41	$5\frac{7}{8}$	33	$5\frac{7}{8}$	$4\frac{1}{2}$	$1\frac{1}{5}$	$4\frac{3}{20}$	$1\frac{1}{2}$	$3\frac{13}{20}$	$1\frac{1}{5}$
1·197	$3\frac{5}{8}$	45	$6\frac{3}{4}$	36	$6\frac{3}{4}$	...	...	...	...	...	...
1·238	$3\frac{3}{4}$	49	$7\frac{1}{4}$	38	$7\frac{1}{4}$	5	$1\frac{2}{5}$	$4\frac{3}{5}$	$1\frac{3}{4}$	4	$1\frac{2}{5}$
1·279	$3\frac{7}{8}$	52	$7\frac{7}{8}$	41	$7\frac{7}{8}$	...	...	...		...	...
1·320	4	58	8	50	8	6	$1\frac{3}{5}$	$5\frac{9}{20}$	2	$4\frac{4}{5}$	$1\frac{3}{5}$
1·400	$4\frac{1}{4}$	65	$8\frac{3}{4}$	55	$8\frac{3}{4}$	$6\frac{7}{10}$	$1\frac{9}{10}$	$6\frac{1}{10}$	$2\frac{1}{4}$	$5\frac{3}{10}$	$1\frac{9}{10}$
1·486	$4\frac{1}{2}$	70	10	60	10	$6\frac{9}{10}$	2	$6\frac{7}{20}$	$2\frac{1}{2}$	$5\frac{1}{2}$	2
1·568	$4\frac{3}{4}$	80	11	65	11	...	..	...	..	...	...
1·652	5	88	$11\frac{1}{2}$	75	$11\frac{1}{2}$	$9\frac{1}{5}$	$2\frac{1}{2}$	$8\frac{7}{20}$	$3\frac{1}{8}$	$7\frac{2}{5}$	$2\frac{1}{2}$
1·733	$5\frac{1}{4}$	93	12	80	12	10	$2\frac{3}{4}$	$9\frac{1}{5}$	$3\frac{2}{5}$	8	$2\frac{3}{4}$
1·817	$5\frac{1}{2}$	100	13	85	13	$11\frac{1}{4}$	$3\frac{1}{4}$	$10\frac{3}{10}$	$3\frac{3}{4}$	9	3
1·899	$5\frac{3}{4}$	110	$14\frac{1}{2}$	93	$14\frac{1}{2}$	$12\frac{1}{4}$	$3\frac{3}{10}$	$11\frac{1}{4}$	$4\frac{1}{8}$	$9\frac{3}{4}$	$3\frac{3}{10}$
1·990	6	118	16	100	16	$13\frac{1}{4}$	$3\frac{3}{5}$	$12\frac{3}{20}$	$4\frac{1}{2}$	$10\frac{3}{5}$	$3\frac{3}{5}$
2·064	$6\frac{1}{4}$	128	$17\frac{1}{2}$	110	$17\frac{1}{2}$	$14\frac{1}{5}$	$3\frac{9}{10}$	13	$4\frac{9}{10}$	$11\frac{2}{5}$	4
2·146	$6\frac{1}{2}$	139	19	118	19	$15\frac{1}{2}$	$4\frac{1}{5}$	$14\frac{1}{5}$	$5\frac{1}{4}$	$12\frac{2}{5}$	$4\frac{1}{5}$
2·229	$6\frac{3}{4}$	150	21	128	21	...	...	...	...	...	...

WORKING LOADS FOR ROPES. Steel wire ropes.—The working load should not exceed one-sixth to one-tenth of the breaking strain ; even a larger margin may be needed if the pulleys are of small diameter, or continuous work at a high speed is required.

The working loads on hemp rope should not exceed 10 to 12 per cent. of the breaking strain.

TIDE RECORDING APPARATUS.—Various appliances have been devised and made for obtaining permanent records of the date, time, duration, and extent of rise and fall in Tidal waters, Reservoirs, etc. That now referred to, constructed for a Colonial Government, provides a permanent diagramatic register of all these conditions, always available for reference.

The recording instrument consists of a drum which carries the chart paper and is caused to revolve by clock work, an indelible pencil in contact with the chart paper recording the time and extent of variation in water level, as described later on. These appliances are fixed on a cast-iron bed—similar to a lathe bed—at a height convenient for observations.

The drum is arranged to receive diagram paper, properly ruled for a record of one month, with datum and cross lines, and is speeded to make one complete revolution in one month.

The pencil holder, with its traversing and tension gear, is connected with a float on the surface of the water, the rise and fall of which is registered by the traverse of the pencil between the vertical lines, the time being recorded between the horizontal lines, during the slow revolution of the drum.

The clock is of the pendulum type, with dial and gear to rotate the chart drum in one month. The chart paper is renewed monthly, and that removed filed for future reference.

The price of the recording apparatus, exclusive of packing and delivery is about £75.

Ruled chart paper for two year's supply costs £12, or £14 for a four year's supply.

TESTING MACHINES.

OIL TESTING MACHINE.—That invented by Professor Thurston, for determining the properties of oils and their true value as lubricants, is perhaps the best known and is quite reliable.

Price of oil testing machine, for bearings up to 1¼ inch diameter, suitable for factories, oil stores, etc. is £9

Oil testing machines for bearings up to 7 by 3¾ inches and for pressures up to 5 tons, as built for railways, cost £50

RECORDING TESTING MACHINE, arranged by Professor Thurston for testing the tensile strength, elasticity, ductility, resiliance and homogeneity of metals or other materials, consists of a strong iron frame mounted on a foundation plate and provided with all appliances for testing metals up to ⅝-th of an inch (16 m/m) diameter under the above-named conditions, and automatically registering the result of each test.

The price of a machine of the above-named capacity and suitable for laboratory work is about £70

STANDARD CEMENT TESTING MACHINE for testing the transverse or tensile strength of sections of the usual dimensions (1½ by 1½ inch) without vibration.

The price of the machine is £35

A set of moulds for test pieces costs ... ... £1 5s.

DYNAMOMETERS, for testing the power absorbed in motion, are made at about the following prices:—

To test up to ... ... H.P.	4	8	20
Price of portable machine	£35	£65	£90
,, fixed ,, ...	£30	£60	£75

MORIN DYNAMOMETERS are driven by belt and record the strain exerted and the number of revolutions made by the shaft, which afford data for ascertaining the power developed in foot-pounds.

PRICES OF MORIN DYNAMOMETERS.

To test up to ... ... H.P.	4	6	10	25
Price of dynamometer	£48	£65	£100	£200

COAL TESTING APPARATUS.—The appliances for testing coal, coke and other fuels to determine their value for heating purposes, are enclosed in a neat case complete with test tubes, glass scales, etc.

The price of the apparatus with appliances for testing lignite and sulphuretted hydrogen gas is ... ... £5 10s.

DEPTH TESTING APPARATUS, for ascertaining by pneumatic pressure the depth in soundings, rivers, wells, tanks and closed or open vessels.

The appliances consist of a small bell—similar to a diving bell—connected by a copper tube to a dial on which is indicated the depth, in feet and inches, the bell has reached in water or other liquid.

The bell is fitted with union joint for attachment to the tube and the prices of the bell and dial are as follows :

Diameter of dial ... ... inches	7	10	10
Price of apparatus	£3	£4	£5

The price of suitable copper tubes is usually about 6d. per foot.

TEST PUMPS for testing boilers, pipes, cylinders and closed vessels by hydraulic pressure up to 300-lbs per square inch, are illustrated and described at pages 113 and 114 of Section III. of this series, but those mentioned below will be found suitable for most purposes.

The price of a test pump mounted on a rectangular cast-iron tank, with hard gun-metal pumps, brass union for connecting with the delivery tube and hand lever, is ... £7 10s.

A portable test pump as above described but mounted on a barrow, costs about £8 15s.

PIPE TESTING MACHINES arranged to test pipes of any diameter or length by hydraulic pressure, consists of a cast-iron bed fitted with head stocks of the height required for the maximum size of pipe to be tested, differential pumps which force the water through the fixed head-stock and automatically cease to work when the desired pressure is reached, and appliances for readily fixing the pipes between the head-stocks.

The price of a machine to test straight pipes up to 9-ft. long and 24-in. diameter is about £150

A machine to test pipes of irregular shape as well as straight pipes not exceeding 9-ft. long or 24-in. diameter, costs about £182

OIL HEATING APPARATUS.—By a modification in the arrangement of the well-known "Wells light," an intense heat is produced; this is used with great advantage in heating bosses of wheels for taking off axles or shafts, also for removing tyres, screw propellers, melting lead joints in water mains, and for similar service.

REFUSE DESTRUCTORS AND POWER PLANTS.—The following notes are extracted from a valuable paper on this subject, contributed to the Proceedings of the Institution of Civil Engineers, in which the author (Mr. C. Newton Russell) deals with the methods of treating garbage or town refuse under three heads, as follows :

(*a*) Removing it cheaply.

(*b*) Disposing of it from a sanitary point of view..

(*c*) Utilising it for steam raising.

The first named—usually cartage to a shoot in proximity to the town—is cheap, but the heap may be a fruitful source of disease and is strongly to be condemned. The accumulation of rubbish in heaps being absolutely dangerous to health, burning is the only safe manner of disposing of it, and so fulfilling the sanitary conditions referred to in paragraph (*b*).

Regarding the question as one of public benefit, the cost of destroying the garbage ought not to be too closely considered, but experience gained in a large number of destructor installations, and especially that at Shoreditch in burning about 25,400 tons of town refuse indicate that—with reasonable expenditure on plant and labour—the heat evolved from the burning refuse can be used with advantage for raising steam.

Calorific value.—The results obtained at Shoreditch show that the average calorific value of domestic London refuse is equal to 0·99 lbs. of water per lb. of refuse burned, and it is estimated that the power obtainable from the whole of the refuse of London is equal to about 133,000,000 brake horse power hours per annum.

Cost of destruction.—They also show that refuse can be destroyed for 2/5 per ton, which is less than the cost of barging it away.

Steam produced.—With refuse as fuel, one boiler and two properly arranged furnaces, the Shoreditch installation evaporated 2·888 lbs. of water per hour, from and at a temperature of 212°, at a steam pressure of 200 lbs. per square inch.

Utilization of steam.—The steam generated as above described supplies the dynamo engines whieh provide current for electric lighting and motive power.

Clinker residual.—This is used—when broken or ground—for making concrete, mortar, paving slabs, tar pavements, etc.

Paving slabs are made of 2½ parts of clinker and 1 of Portland cement, ground very fine, and submitted to a pressure of 1¼ tons per square inch.

The slabs are usually 2½ inches thick, and range in dimensions from 2 feet square to 3 feet by 2 feet. A slab supported at the ends sustained a load of 2,221 lbs. before breaking.

It is found that slabs made of five parts of broken clinker and one part of Portland cement, pressed as above described, are very satisfactory and not slippery.

Tar paving.—Broken clinker, sifted to the sizes required for bottom and top dressing, is used with advantage for tar paving, and seems about equal, in durability, to the ordinary granitic tar pavement.

Reverting to the remarks on "calorific value" it is scarcely probable that the results obtained at Shoreditch– where there is a large proportion of trade refuse—will be equalled in districts which are largely residential and non-manufacturing. In such localities the most wholesome mode of disposing of refuse will be simply to burn it, and make the best one can of the waste products. The idea that a Destructor must necessarily emit unwholesome fumes is altogether fallacious.

Notes on paving slabs, etc. and plant for manufacture will be found at page 245 and 264.

ICE MAKING AND WATER DISTILLING.—The following is an outline description of plant suitable for a hot climate, where a moderate quantity of pure ice is required and a permanent supply of sufficiently pure water is not obtainable.

The plant referred to is capable of producing in England one ton of ice in 24 hours, but similar plant—with or without distilling apparatus—is arranged for larger quantities.

The ice making plant consists of a belt driven compound ammonia compressor working in connection with an open air condensor, and ice tank which contains the refrigerator coils. This arrangement saves joints and possesses other advantages.

The wrought iron ice tank contains twenty ice moulds 3-ft. by 1-ft. 6-in. by 3-ft. and is fixed on one side of the ice store which is constructed of pitch pine and lined with sheet lead, the walls being 9 inches thick with sawdust between the inner and outer walls for insulation. The brine is circulated around the ice mould and refrigerator coils by a propellor with suitable driving gear.

Power is supplied from a vertical engine; the exhaust steam passes through a feed water heater, and the boiler is of sufficient capacity to drive the engine and pump which raises the sea water to be distilled, also to supply steam to the distiller.

The distilling apparatus supplies 15 gallons of distilled water per hour, and consists of copper coils fixed in a tank of ample dimensions and supplied with cooling water by an independent steam pump, so that distilled water can be produced without running any other portion of the plant. The distilled water flows by gravitation into a tank and thence to the ice moulds as required.

The cost of the plant including all tubing, shafting, bearings, belts, a supply of ammonia and oil, instruments, wrought iron chimney for boiler, etc. is about £900

Packing for shipment and delivery f.o.b. costs about 5 per cent.

The cost—in England—of a suitable building with Engineer's office and space for the necessary tools, stores, etc. may be assumed to be, approximately £250

Information required.—If a complete specification cannot be supplied, details should in all cases be given relating to output, maximum and minimum temperature, plan of site for the installation and such other data as will clearly define the conditions to be fulfilled.

LARGE INSTALLATIONS FOR ICE MAKING AND REFRIGERATING. The plant does not differ materially from that last referred to, excepting as to proportions and arrangements to minimise manufacturing cost.

SMALL ELECTRIC LIGHTING AND POWER INSTALLATIONS.

The following remarks and information—extracted, for the most part, from "The Engineer"—set out in considerable detail the cost and comparative advantages of each system, and are the more valuable in that data is furnished whereby the approximate cost of current may be ascertained, even if the rates and quantities differ from those tabulated.

"The question whether it will be better to put down a private installation, or take current from a supply company's or corporation's mains, is one often asked by intending users of electric light, and an attempt to give some idea of the relative cost in each case, together with the advantages and disadvantages of each system, may be of use to such persons, and perhaps of interest to others."

For simplicity and accuracy, the quantities and time of lighting are uniform throughout, and the cost of wiring, lamps, fittings, fuses and branch switches, is not taken into account because these items will vary in different installations, although identical whatever system is adopted.

CURRENT FROM SUPPLY COMPANIES' MAINS.—The annual cost of current at different rates per B.T.U. respectively for 50 and 100 16 candle-power 60 watt lamps burning 1800 hours per annum, including rent of meter (20/- and 25/-), is as follows:—

ANNUAL COST OF CURRENT FROM PUBLIC MAINS.

Rate for current per B.T.U. pence	2d.	3d.	4d.	5d.	6d.	7d.
Annual cost for 50 lamps ...	£46	£68 10	£91	£113 10	£136	£158 10
,, ,, 100 ,, ...	£91 5	£136 5	£181 5	£226 5	£271 5	£316 5

CURRENT SUPPLIED BY PRIVATE INSTALLATIONS.—The following information will be useful when the kind of plant most suitable for local conditions is under consideration, the estimate—in each case—being for an installation to generate current, respectively, for 50 and 100 16 candle-power 60 watt lamps burning 1800 hours per annum.

The cost of plant includes that of engine and dynamo with the necessary fittings and appliances, foundations, erection and cost of switch board, but—as already indicated—no wiring or accessories connected therewith.

Supervision and cost of attendance are referred to later on.

Interest and depreciation.—The estimates allow for interest on capital at the rate of four per cent. per annum and ten per cent. per annum for depreciation.

Fuel —The cost of coal is taken at 20/- per ton, including cartage, and the consumption for the smaller steam engine is assumed to be 5-lbs. of coal per brake horse-power per hour, and for the larger engine 4½-lbs.

The engines are estimated to be of 5 and 10 horse power, but to give out an everage of only 4 and 8 brake horse-power, which leaves a sufficient margin of excess power.

Gas and oil engines.—The smaller gas engine is estimated to consume 22 cubic feet of gas per brake horse-power and the larger one 20-cubic feet, the price of gas is assumed to be 3/3 per 1000 cubic feet. This cost will be very largely reduced if gas producer plant is provided.

The oil engines are taken to each consume 1¼-lbs. of oil per brake horse-power hour, and the oil is assumed to cost 6d. per gallon.

Engines and dynamos can be obtained at less cost than the figures tabulated, but some makers charge more for them, so an average has been taken.

Turbines.—The principal expense in putting down an installation driven by a turbine is often incurred in making suitable water ways and the pit for the turbine; for the present purpose the cost of water channels, pits and foundations has been reckoned to be equal to the cost of the complete turbine; in some cases this provision will be insufficient, although more than ample where a stream with sufficient fall is available near to the premises to be lighted.

Oil, stores, etc.—The cost of oil, waste and stores is reckoned at about one third of one penny per unit of current generated.

COST OF PRIVATE INSTALLATIONS.

Motive power	Steam Engine	Gas Engine	Oil Engine	Turbine
Cost of plant for 50 lamps ..	£218 0 0	£180 0 0	£190 0 0	£182 0 0
Annual cost of fuel	£16 0 0	£25 14 9	£26 9 0	..
,, ,, attendance ...	£65 0 0	£39 0 0	£39 0 0	£19 0 0
,, ,, stores, oil, etc...	£7 10 0	£7 10 0	£7 10 0	£6 10 0
Interest on capital & depreciation	£28 15 0	£23 5 0	£24 12 0	£18 6 0
Total annual cost	£117 5 0	£95 9 9	£97 11 0	£43 16 0
Cost of plant for 100 lamps ...	£332 0 0	£237 0 0	£310 0 0	£257 0 0
Annual cost of fuel	£29 0 0	£46 16 0	£52 18 0	...
,, ,, attendance ..	£65 0 0	£39 0 0	£39 0 0	£19 0 0
,, ,, stores, oil etc,...	£11 5 0	£11 5 0	£11 5 0	£10 0 0
Interest on capital & depreciation	£44 10 0	£31 4 0	£41 8 0	£26 6 0
Total annual cost	£149 15 0	£128 5 0	£144 11 0	£55 6 0

PRIVATE INSTALLATIONS WITH ACCUMULATORS.—The generating plant is as last described and the accumulators have a capacity sufficient, in each case, to supply about 50 lamps for a period of three or four hours; they add materially to the cost of the installation, but ought to be provided, especially in private houses.

COST OF PRIVATE INSTALLATIONS WITH ACCUMULATORS.

Motive power	Steam Engine	Gas Engine.	Oil Engine.	Turbine.
Cost of plant for 50 lamps ...	£330	£292	£302	£300
Annual cost of fuel	£16 0 0	£25 14 9	£26 9 0	...
,, ,, attendance ...	£72 16 0	£41 5 0	£41 5 0	£21 0 0
,, ,, stores, oil, etc. ...	£8 10 0	£8 10 0	£8 10 0	£7 0 0
Interest and depreciation ...	£43 14 0	£38 14 0	£39 13 0	£35 0 0
Total annual cost	£141 0 0	£114 3 9	£115 17 0	£63 0 0
Cost of plant for 100 lamps ...	£450	£355	£428	£382
Annual cost of fuel	£29 0 0	£46 16 0	£52 18 0	...
,, ,, attendance ...	£72 16 0	£41 5 0	£41 5 0	£21 0 0
,, ,, stores, oil, etc. ...	£12 10 0	£12 10 0	£12 10 0	£10 10 0
Interest and depreciation ...	£60 10 0	£47 4 0	£57 11 0	£44 10 0
Total annual cost	£174 16 0	£147 15 0	£164 4 0	£76 0 0

Conclusions.—Several interesting conclusions are drawn from these tables; they show, for instance, that a private installation without an accumulator, driven by a turbine supplies the current at less cost than if it is taken from a supply company, even at the low rate of 2 pence per Board of Trade Unit. Also that for such small installations a steam engine is more expensive than gas or oil engines, or turbines, the annual cost with gas or oil engines being nearly equal for the smaller installation, but considerably in favour of the gas engine for larger installations, on account of the greater ratio at which the prices of oil engines increase with their size.

Comparative cost of current.—Another important point brought out in these tables is, that whereas the cost of lighting 100 lamps is twice as much as the cost of lighting 50, with current taken from a supply company's mains, with a private installation the cost of lighting 100 lamps is never 50 per cent. greater than the cost of lighting 50, and in the case of turbines is only about 20 per cent. greater.

It will also be seen that a gas engine installation, with accumulators for 50 lights, costs about as much per annum as current from supply company's main at 5d. per Board of Trade Unit, but with a similar installation for 100 lights the cost is considerably less than is paid for a public supply at 4d. per unit. In any case private installations are cheaper than public current at 7d. per Board of Trade Unit, especially if producer gas is used.

Relative advantages.—The disadvantages of a steam engine and boiler are such as to prohibit their use in the majority of cases ; they occupy more space and require more attention than the other prime movers, and the coal causes dirt and smoke.

Gas or oil engines, on the other hand, can be fixed in a cellar or outbuilding, the fuel is brought to them free from dirt or trouble, they can be started in a few minutes, they will run for hours without attention, and there is little danger of explosion. These advantages are greatly in favour of engines of this type and conduce to make them preferable to other motors of small power, excepting the turbine ; but as turbines can rarely be used in towns, the gas engine remains supreme in crowded places or where gas can be obtained at a reasonable price. Where it is high—or not obtainable—an oil engine is an excellent substitute, provision being made for carrying away the fumes inseparable from the use of mineral oils.

Supervision.—Many people have exaggerated ideas with regard to the trouble involved in erecting and running a private installation. They imagine that dirt, smell, noise and danger are inseparable from such installation. As a matter of fact, if the plant is judiciously chosen and properly fixed, it should cause no nuisance whatever, and will be much more economical than taking current from public supply mains.

Cost of attendance.—It has been assumed that an intelligent labourer, at 25/- per week, will be quite capable of attending to the steam plant; a youth at 15/- per week will soon learn to look after a gas or oil engine installation, and these rates have been used in preparing the foregoing estimates.

Part attendance only has been allowed for the turbine plant, and as the same attention is required for an installation of 50 lights as for one of 100 lights, the amount for wages is the same, an extra shilling or two being added to cover the cost of attending to the accumulators.

ARC AND INCANDESCENT LAMPS.—The arc lamps now referred to burn steadily, two in series, off a 100 volt current, with only a small resistance inserted, and the carbons are easily renewed.

The larger sizes are suitable for lighting large areas, in or outdoor, the smaller size being useful where less powerful illumination and a light lamp occupying little height is required.

PRICES OF ARC LAMPS.

Current	amperes	5	7	10
Lighting capacity	hours	8	16	16
Length of carbon	inches	6	12	12
Total height of lamp	,,	22	35	35
Price of lamp and globe	...	£5 10	£6 10	£7
Price of resistance	...	15/-	17/6	17/6
Approximate total weight	lbs.	14	35	35

The cost of packing for shipment and delivery f.o.b. will probably be about 5 per cent. or a little more.

AVERAGE LIFE OF LAMPS IN HOURS.

Watts per candle power.	Life on Accum. at constant E.M.F.	1 per cent volts up.	2 per cent volts up.	3 per cent volts up.	4 per cent volts up.	5 per cent volts up.	6 per cent volts up.	7 per cent volts up.
4·5	2,200	1,900	1,700	1,450	1,300	1,100	950	820
4·0	1,550	1,400	1,150	950	850	750	660	600
3·5	1,000	850	700	660	600	530	470	440
3·0	600	520	470	440	380	330	290	250
2·5	300	270	250	220	200	180	150	130
2·0	150	130	120	110	95	85	70	...

PRICES OF INCANDESCENT LAMPS.—The prices of these vary according to the candle power, voltage limits, and size and shape of bulb, from 1/6 to 3/- each, taking the range from 8 to 50 candle power; for 100 candle power, 7/- each. These particulars should always be given when seeking quotations. It is always more economical in the long run, and when the current consumed is taken into account, to purchase the best quality of lamp, in preference to so-called cheap lamps. As regards the life of lamps, the foregoing table gives an idea of what may legitimately be expected with a first-class lamp, apart from abnormal treatment.

TELEGRAPHS AND TELEPHONES.

MATERIALS FOR TELEGRAPH & TELEPHONE INSTALLATIONS.

The following data relates to installations suitable for works in course of construction, branch lines, quarries, factories, etc.

Five miles of line, with metallic return and a telegraph or telephone instrument at each end, has been adopted as a convenient unit, but the approximate outlay required for additions to the length of line, or to the number of instruments, will be found by reference to the accompanying schedule of prices.

Poles and labour.—The cost of these items is given separately because (being based on current rates of cost in London) they may not at all accurately represent local costs elsewhere; they may, however, serve for purposes of approximate estimate.

The materials comprise:

Five miles of No. 14 hard drawn copper wire line with metallic return.

Fittings for carrying line, consisting of arms, bolts, insulators, shackles, stays, leading-in-wires, and sundries.

Instruments (telegraph or telephone) at each end.

The price of these materials and instruments is about £150

Earth return.—If this is used instead of the double line metallic return, the cost is reduced by about £50

Electrician's tools.—A small equipment for use in laying and maintaining the line costs about £20

Creosoted poles for five miles of line, cost about £130

The cost of labour and superintendence for erecting such an installation (in London) is about £150

PRICES OF INSTRUMENTS AND MATERIALS FOR LINE WIRES.

Single needle reading instruments, each about	£5
Relay tapper bells	£4
Magneto telephone instruments, railway pattern	£4
Telephone with relay and bell, Great Western Railway pattern	£4/10
Six-cell Leclanche battery	15/-
Twelve-cell Leclanche battery	30/-
Creosoted telegraph poles, 18 feet, each	15/-
,, ,, ,, 30 feet ,,	30/-

Roof, arm, arm-bolts and washers, insulator, shackle with strap and bolts for each pole, 4/6

Stay rods 3/- each. Creosoted stay blocks 2/6 each.

Hard-drawn copper wire, No. 14 B.W.G. for line wire costs per mile about ... £7

Accessories.—A small provision should be made for iron wire stays for poles, nails and sundries, but probably 1/- to 2/- per pole will suffice.

TUBULAR STEEL POLES for supporting telegraph wires, electric light and power cables, boundary demarcation lamps, etc. are made in all lengths and sections, the under-named being standard dimensions.

The base tube is of cast iron and fitted with a cast iron disc to give the requisite stability, but removable for transport.

The pole fits on the top of the base pole and is made of galvanised steel rivetted up in lengths of 8 feet; these taper upwards and are connected by joint rings easily fixed by unskilled labour, no bolt or rivets being required.

The cast iron base tubes are also used, with great advantage, for carrying timber poles.

The prices and weights are approximately as follows, and the cost of delivery f.o.b. depends on the kind of packing required and the port of shipment, but this will probably not exceed 3 or 4 per cent.

PRICES OF TUBULAR STEEL POLES.

Height of pole feet	15½	23	30¼	37⅓	46½	51¼	58¼
Price ... each	£1 19 6	£2 13 9	£4 6 3	£6 13 2	£9 0 6	£11 9 0	£13 7 9
Approx. weight lbs.	210	287	460	710	962	1220	1480

INSULATOR FITTINGS—The insulators are usually supported by malleable cast iron brackets which are attached to the pole by clip bolts, but they vary too much in length, section and other details to admit of them being tabulated.

TRAMWAYS.

The prominent advantages of mechanical over horse traction are: The absence of refuse to be removed, the larger carrying capacity for a given length of car (including that occupied by the horses), the much greater facility for mounting gradients and for stopping and starting, and complete control of mechanism.

The relative merits of the different systems of traction in common use are referred to in a paper by Mr. Parker which was read before the Institution of Civil Engineers and which contains the following valuable information relating to average results obtained.

The electric system referred to, was supplied with current from overhead conductors which, so far, seems to be the most economical mode of transmitting power and the easiest to maintain.

System of traction	Horse	Steam	Cable	Electric
Passengers carried	26	54	54	30
Expenses, pence per car mile	7·78	8·99	4·40	3·157
Weight of car empty... ... tons	2·75	12	4·7	4·3

Cost of traction tramway (England).—The following figures, amplifying those preceding, give the average approximate cost of traction by the respective systems, including all running charges and repairs.

Horse traction, in a hilly city ... ... 10·17d. per car mile.
Steam traction, ditto ... ... 10·33d. „
Electric traction, ditto ... ... 4·83d. „
Cable traction, on fairly level roads ... ... 6·40d. „
Compressed air car traction, undulating ground ... 7·39d. „
Ditto, locomotive traction, ditto ... 8·28d. „
Gas motor traction, on fairly level roads ... ... 3·47d. „

This cost is based on a consumption of 34 cubic feet of gas per car mile for cars carrying 52 passengers.

The details of cost are: Gas, 0·95d. per car mile; water, 0·13d.; oil and waste, 0·10d.; drivers, 1·15d.; cleaning, 0·10d.; compressing, 0·15d.; depreciation and repairs, 0·89d. Total 3·47d. per car mile.

Oil engine traction costs about the same as gas motor traction if the price of gas is 2/9 per 1000 cubic feet.

DETAILS OF COST OF ELECTRIC TRACTION.—The undernamed figures are stated by Professor Kennedy to represent approximately the average of each item of cost.

Drivers, Conductors and Inspectors	42 per cent.
Power	18 per cent.
Maintenance of line	12 per cent.
Equipment	12 per cent.
General charges	16 per cent.

He also states that in some cases the cost of generation has been reduced to 10 per cent. and—evidently—the importance of ensuring the highest possible efficiency in the power-house cannot be too strongly urged.

COST OF TRAMWAY TRACTION IN NEW YORK—The subjoined figures abstracted from "The Street Railway Journal" give the cost of haulage in New York in the year ending 30th June, 1899, respectively for cable, electric, and horse traction.

WORKING EXPENSES.

Details of items	Maintenance of way.	Maintenance of equipment.	Cost of power.	Other expenses.	General expenses.
Cable traction, pence per car mile	2·34d.	·56d.	1·19d.	4·21d.	·67d.
Electric ,, ,, ,,	·34d.	·58d.	·88d.	3·53d.	·63d.
Horse ,, ,, ,,	·49d.	·21d.	3·34d.	4·12d.	·81d.

"**Other expenses**" include wages, car-house expenses, lighting, oil, waste, etc.

General expenses include salaries of officers, clerks, compensation and damages, and sundries not specified.

FINANCIAL RESULTS.

Details of items	Receipts.	Expenses.	Profit.
Cable traction ... pence per car mile	17·71d.	9·00d.	8·71d.
Electric ,, ... ,, ,,	15·61d.	5·97d.	9·64d.
Horse ,, ... ,, ,,	12·85d.	8·97d.	3·88d.

Receipts—If the above figures are compared with gross returns obtained elsewhere, it should be remembered that fares are much higher in New York than they are in most European Cities.

LOSS OF ELECTRIC POWER IN STOPPING TRAM CARS.—The consumption of power in stopping electric tramcars, travelling at different speeds and with stops of 8 to 10 seconds, is stated by Mr. A. H. Binyon to be as follows, the weight of car being 12 tons, and the power consumed expressed in Board of Trade Units.

LOSSES OF POWER IN STOPPING.

Speed per hour ... miles	6	7	8	9
Number of stops per mile ...	6 to 14	6 to 13	5 to 11	4 to 9
Power lost ... B.T.U.	.7 to 1·08	.65 to 1.43	·75 to 1·75	·73 to 2

Speed per hour... ... ... miles	10	11	12
Number of stops per mile	4 to 8	4 to 8	4 to 8
Power lost ... ... B.T.U.	·82 to 2·20	·78 to 2·04	·73 to 2·04

EFFICIENCY OF ELECTRIC TRAMWAY PLANT.—The following figures, relating to efficiency under a constant load, are extracted from a record of 24 hours test of a plant recently put down for the Washington (U.S.) tramways; equal efficiency will, however, be quite unattainable under widely varying loads:

Cost of coal	8·9 shillings per ton
Cost of power per one H.P. ...	0·10d. per hour
Cost of power, electrical H.P. ...	0.103d. ,,
Cost of electrical H.P. per year of 3000 hours	£1 5s.

COST OF DIFFERENT SYSTEMS OF ELECTRIC TRAMWAYS.—In addressing the Municipal Electrical Association, Mr. Ryder (President) points out that the cost of construction for the three distinctive types of electric traction vary largely according to local conditions, but that the cost per mile of single track, including rails and paving in each case, are generally somewhat as follows :

Overhead construction	... ...	£5000 per mile
Surface contact construction	...	£10500 ,,
Conduit Construction	... ...	£13500 ,,

and he indicates that the conditions are few and far between which justify the extra outlay for the two more expensive modes of construction.

COST OF GENERATING AND DISTRIBUTING ELECTRIC CURRENT.—This naturally varies according to the extent and character of plant, efficiency of management, price of fuel, number of units sold relatively with capital outlay, staff charges, etc. but an analysis of accounts of six comparatively small and widely separated public installations, including maintenance of mains, machinery, buildings and accessories, was 2·41d. per unit.

The capital outlay on these six installations ranges from about £30,000 to £97,000 the average being about £47,600.

TRAMCAR CRANES.—In order to avoid the expense of a long pit in new stations, or interference with traffic in existing stations, a pair of electric or hand power cranes raise the car to a height which affords all facilities for examination or repair.

Construction.—These cranes (one at each end of the car) are mounted on an undercarriage which travels on a crane track parallel with the tram line.

The jibs are curved at the upper end and reach to the car, so that the lifting chain being attached to a suitable sling, the whole car, or the body only, is raised sufficiently for men to work beneath it.

A pair of cranes recently built have travelling motion for removing the car for substantial repairs, or other purpose, and this and the lifting motion can be operated either by electric or hand power.

TRAMCAR SHED TRAVERSERS see page 51.

NOTES ON TRAMWAYS & ROAD PAVING.

The following notes on these important subjects, extracted from a thoughtful article in "The Engineer" are intended briefly to indicate the economical and general results obtained under different systems, and are the more valuable from the fact that they are records of practical experience.

TRAMWAY RAILS, if of the Vignoles section, usually range from about 60-lbs. to 75-lbs. per yard, and their life is variously estimated at 6 or 7 to 25 or 30 years. The former is no doubt a low average, but when allowance has been made for the injury caused by frequent repairs to roads carrying tram-lines and the great wear and tear at joints and on curves, the writer finds that seven years is not very much too conservative an estimate.

Bogie trucks and fixed wheel base.—The superiority of cars mounted on bogie trucks over those with fixed wheel base has been amply demonstrated unless the road for the latter is practically straight.

Examples of this are found on lines with electric traction and 10-ton cars with fixed wheel base traversing sharp curves and steep gradients. Lines with heavy traffic worked under these conditions have had to be renewed in two or three years. Notes on the junction of rails with paving will be found further on.

ROAD PAVING.—Pavements for cities and towns may be generally classified as those formed of wood, granite or other blocks, and those with continuous surface, such as asphalte and macadam.

The essential features of good pavement are:

1. It must be durable, and economical both in first cost and subsequent repairs.
2. It must be hygienic and—in this respect—free from mud and dirt, easily cleansed and noiseless.
3. It must afford a good footing for horses in both wet and dry weather, and require the smallest possible tractive effort to propel vehicles over it.

Wood block paving, laid on a concrete foundation six to eight inches thick, is fairly durable, the life (in London) being six to nine years.

Cost of laying and repairs.—The cost of laying is 8/- to 10/- per superficial square yard, and repairs cost 7d. to 10d. per square yard per annum, so that it may be regarded as fairly economical.

Conditions 2 and 3.—It is the most perfect paving as regards noiselessness, there is very little dust and it is unrivalled in safety to animals, in wet or dry weather, and economical in tractive power.

The principal drawbacks to it are, its tendency to absorb malodorous matter, and the large quantity of water required to thoroughly cleanse it.

Granite sett paving.—The setts (usually 9-in. by 3-in. and 6 to 8-in. deep) laid on a concrete foundation 6 to 8-in. thick, costs about 16/- to 18/- per square yard.

With once relaying, it lasts 20 to 30 years and the cost of repairs is only about 2d. per square yard per annum. It is, therefore, much the most economical form of paving, and, being non-absorbent—is easily cleansed. It also affords a good foothold for horse traction, but it is less favourable than wood for a fallen horse and is very noisy.

For this reason the more silent, but less durable, kinds of paving are frequently preferable.

Gritstone paving. laid in the same manner as granite, is principally used in districts where the material abounds. It is much cheaper than granite but there are serious drawbacks to its use. These are that it wears very quickly and unequally under heavy traffic, which causes great expense in maintenance and loss in tractive power. Furthermore it is noisy and much more dusty than either granite or wood paving.

Scoria briquettes.—Blast furnace slag is run into moulds about 9-in. by 3-in. and the road bed for these sets is similar to that used for granite sets.

It is cheap in first cost but expensive in maintenance, and wears more unevenly than gritstone under anything like heavy traffic; the dust from it is very objectionable.

Brick setts, also laid like granite setts, are clean and are used in some countries for road paving, but they wear very rapidly under wheeled traffic; they are, however, very agreeable in side walks.

Asphalte.—The rock, as found, contains about 88 per cent. of carbonate of lime and 12 per cent. of bitumen and forms an excellent but rather expensive road paving.

The cost of asphalte paving, with concrete foundation 6-in. deep covered with asphalte 2-in. thick is 13/- to 14/- per superficial square yard. The repairs cost 10d. to 1/- per square yard per annum.

The life of asphalte paving is estimated at 12 to 15 years, and it is repaired with far less interference with traffic than that incidental to any other kind of paving.

It is impervious to moisture, and the surface being smooth and level, it is easily cleansed. The tractive effort for draft of vehicles is slightly lower than on wood paving and the principal objections to it are the heavy first cost and the extremely slippery surface, wet or dry.

Paving in conjunction with tram lines.—Some trouble is caused by the rapid wear of the portion of paving which adjoins the tram rails, and by spreading caused by expansion.

These inconveniences are more noticeable in wood than in stone sett paving, which of course does not expand, but they can be remedied by using a certain per centage of iron blocks in the pavement abutting against the rails.

Asphalte presents the greatest difficulties on account of its tendency to flow, and to its constant movement, peculiarities which it is by no means easy to counteract.

NOTES ON POWER TRANSMISSION BY ELECTRICITY.

The following are the conclusions arrived at by the Committee appointed by the American Railway Master Mechanics Association, to examine and report upon:

1. Relative economy in cost of power itself.
2. Relative convenience of operation and installation.
3. Relative effect on shop output and cost of labour, under the best practice in driving machine tools.

Relative economy.—The average efficiency from engine to tools, for belt transmission is about 50 %

For electric transmission, long lines of shafting being broken up, the efficiency from engine to tools is stated to be about 60 %

Electric is, therefore, more economical than shaft transmission, but if a large condensing engine displaces small non-condensing ones and the load is uniform, the fuel saving will be approximately $33\frac{1}{3}$ %

Attendance and repairs.—Careful examination leads to the conclusion that these items do not differ materially under either system of driving, but the former offers facilities for improvements in labour-saving devices, the value of which can scarcely be estimated.

Interest and depreciation may (together) be taken at 10 per cent. on the first costs of either mode of transmission or—approximately—one-fourth of the total expenses of the power system.

Relative convenience and output.—The absence of restriction as to positions of machines driven by electric motor, the clear head room for overhead cranes to serve the tools, and the saving in power effected by stopping the motor when the machines are not working, all conduce to economy in cost of production and in space occupied, as well as to augmented output.

These features, and the flexibility of the electric system which admits of the use of portable tools, of fixing tools where they will work with maximum economy, or of extending shops in any direction, are worthy of careful consideration.

POWER REQUIRED TO DRIVE MACHINE TOOLS.—The table, at pages 250 and 251, giving the power required to drive many kinds of tools and machines will be useful when the total motive power to be provided is under consideration.

In this connection, it may be well to mention that the variations in load and from line losses, are about as follows:

Generators ...	... 86	to	90	per cent.
Transmission lines	... 90	,,	95	,,
Motors	... 78	,,	90	,,
Total final efficiency	... 62	,,	77	,,

Systems of dynamos and motors.—The alternating current system is recommended for transmitting power one mile or more and the direct current system for shorter distances.

The former is preferable, mechanically, on account of the strength and simplicity of construction, and the absence of rubbing contacts; but it is essentially a high speed, and constant speed machine, and these features are much less favourable for driving many machines, cranes, etc. than the direct current system which will start under load, run at variable speeds, or stop and reverse.

These facilities are not afforded by the induction (or alternating current) system, and when they are required, as they are, for boiler plate rolls, cranes, hoists, capstans, traversers and many other mechanical appliances, series wound motors are preferable.

Voltage.—The 250 volt direct current motor is, practically, the standard for shop use, and incandescent lamps can be obtained for 220 volts circuit, or the more common 110 volt lamp may be used by connecting two of them in series.

A 250 volt dynamo, therefore, is recommended, because, allowing for ordinary losses in lines, this corresponds to motor pressure of 220 volts.

Alternating current motors are wound for either 220 or 440, and for reasons similar to the above, a 250 volt system is recommended.

Type and size of dynamo.—A belt driven dynamo has the advantage in first cost, due to the higher speed, which means more output for the same outlay, and the further fact, often of great importance, that it can be driven by an existing engine or any kind of motor.

Up to 75 to 100 horse-power, a belt driven dynamo usually answers every purpose, but beyond that power, direct connected machines will be found more economical.

Uniformity.—Much importance is attached to uniformity in units of size, 500 horse power direct connected dynamos being advocated as a convenient unit for large plants.

Uniformity, as far as possible, in units of size of motors, is equally desirable, and to attain this, some theoretical losses due to motors being larger than actually necessary, may be tolerated.

Motor capacity.—As regards the dynamo capacity to be provided, it is pointed out that the motor load, in an ordinary shop, seldom runs above 50 per cent. of that of the combined motor capacity; also that the effect on the dynamo of running a crane, traverser or turntable need not be considered, because the momentary over-load capacity of the machine will be ample to provide for such requirements.

Motor speeds.—Seeing that the lower the speed of the dynamo or motor, the greater is its durability, first cost is of far less importance than the economical results obtained by the installation of machines of ample proportions and obtained from reliable constructors.

Guaranteed power.—Motors should be guaranteed to develop their maximum power continuously, and carry an over-load of 25 to 50 per cent. for two hours, without rise of more than 40 degrees Cent. above the temperature of the surrounding air.

Prices and speeds of motors.—The following table gives the speed, direct current, multipolar motors, which fulfil the above-named conditions.

SPEEDS AND PRICES OF MOTORS.

Rated output, H.P.	2	3½	5	7½	10	15	20	30	40	50
Speed, revs. per min.	1200	1050	950	850	750	650	600	575	550	550
Price of motor about	£27	£38	£48	£62	£80	£100	£120	£170	£210	£240
,, per H.P. about	£13 5	£11	£9 12	£9 2	£8	£6 12	£6	£5 12	£5 4	£4 17

Plus cost of packing and delivery.

Medium speed motors, of equal quality, cost about 20 per cent. less for the smaller sizes, and 35 per cent. less for the larger sizes, the same power being developed with speed revolutions about 50 per cent. higher.

Distribution of power.—When less than three horse-power is required for each machine, it is considered best to drive them in groups, from short-line shafts requiring not more than 25 aggregate horse-power.

Machines requiring three horse-power, or more, or where variable speed or intermittent running is desirable, each tool should have its own motor.

In the group system, transmission by belt reduces shock and prolongs the life of the motor, and is considered to be better for general use than driving by gear, or by coupling the motor spindle direct to the lay shaft.

Conclusions.—These cannot be better or more tersely expressed than they are in the words of the Committee's report:

"1. **In a small shop** consisting of, practically, one building, having an equipment of small tools for light work only, electric transmission will not be found to be a paying investment.

In such shops, however, an electric lighting dynamo will be a convenience, and may be utilised to run a few labour-saving electric tools, such as drills, a cylinder boring machine outfit, a turn-table motor, etc.

2. **In an extensive shop plant,** the installation of a central power station and electric transmission will always be found advisable, as it will not only result in the most economical system in respect to operation, but will make possible far more important economies, namely, an increase in the quantity and quality of output, and a reduction in the cost of handling the same." Examples of these results are given further on.

DESCRIPTIONS OF SYSTEMS OF ELECTRIC TRANSMISSION.—The following abstract from the Master Mechanics' report, will be interesting to those who are not already familiar with the subject. The systems in general use are:

The direct or continuous current, which means a flow of current, in one direction, along a wire; and

The alternating current, or a reciprocating flow analagous to the to and fro movement of an engine piston.

The first-named, being a relatively low pressure system, requires larger and more expensive copper conductors to convey the current, than the alternating current system which transmits high pressures, and, consequently, small volume over a small line-wire, and is, therefore, preferable for long distance transmission.

MAIN ELEMENTS IN ELECTRIC TRANSMISSION.—These are:

1. The generator or dynamo which produces electric energy from mechanical.
2. The transmission wire for carrying current; and
3. Motors for converting electrical into mechanical energy at points where it is to be used.

ELECTRICAL UNITS.—The size of a generator is expressed in terms of its electrical output in "Watts," an expression which means the product of the volts pressure by the number of ampères of the current.

As, however, a watt is an inconveniently small unit, it is customary to rate machines by a multiple called a "Kilowatt" (K.W.) which means 1000 watts, or about 1⅓ horse power.

DYNAMO OR GENERATOR.—This consists of a stationary part with bearings, and a revolving part, the shaft of which is connected with the source of power.

One of these parts constitutes the "field," and is provided with magnet poles, while the other constitutes the "armature" in which the currents are induced by rotative movement of its wires in the strong magnetic field.

The direct current generator is provided with a "commutator" and brushes for rectifying the alternating current produced in the armature. This type is sub-divided into "constant speed" and "variable speed." The former is known as the "shunt motor" and the latter may be either "compound wound" or "series wound."

The series wound motor, the speed of which varies in direct proportion with the load and current, is best adapted for cranes, capstans, electric traction, and all service where a powerful "torque," or turning motion, is required in starting, stopping and reversing.

All direct current motors require a "resistance box" with heavy wires to choke down the current and prevent excessive heating of the motor in starting, and to automatically adjust the pressure of current.

The alternating generator needs no commutator, the current being taken off from continuous collector rings, but its magnets must be supplied with continuous current from a small separate machine called an "exciter."

"Alternating current generators are further sub-divided into "single phase" and "multiphase," terms which refer to the kind of alternating current produced. This can be best explained by the following mechanical analogy:

An engine shaft may have a single crank, or two or more cranks set at, say, 90 degrees or 120 degrees, the turning motion at each crank rising, falling and reversing in succession.

In the same way, alternating currents may act in a simple wave, or in several waves acting successively. The advantages of multiphase currents lie in the peculiar properties of the motors which are possible with this system."

Switchboard.—Generators are provided with a "Switchboard," usually a marble or slate panel, fitted with safety devices, measuring instruments, and switches for electrically connecting it with the various lines of wire leading to the points at which the current is to be utilized.

The line consists of wires, of the requisite size or current carrying capacity, covered with insulating compound, and carefully laid to ensure safety from fire and to avoid waste of power.

"The size of the wires is governed by two considerations:

(*a*) The safe heating limit with the amount of current to be carried.

(*b*) The loss of power entailed by heating.

Line losses.—The loss in heat (and pressure) between the generator and the motor, may amount to 10 per cent. and this should be allowed for in determining the size of the conductors, the heating limits of which can be ascertained from various tables.

Laying out lines.—The rules for laying out a distributing system are the same for either direct or alternating current, but the former—requiring only two wires for outgoing and return—is the more simple.

The polyphase alternating current requires three or four wires for each feeder line, and if a change of pressure is necessary, a "transformer" is inserted in each feeder line.

ECONOMICAL RESULTS OF ELECTRIC TRANSMISSION.—Remarkable and almost unexpected economies have been obtained by the intelligent application of this mode of transmission in large works. Many examples of this might be given, but perhaps the following may suffice.

2000 horse-power plant.—Works employing boilers of 2000 horse-power, and thirty high class compound engines transmitting power to line shafts for driving the machines, found that the superior economy of electric transmission would provide the larger power required for extensions then found necessary, without increase in the existing boiler plant.

Tests made, after the installation of the electric plant, showed a saving in its favour of 33 per cent. in fuel, and 40 per cent. in the quantity of water consumed.

Large locomotive shops.—Another example is afforded by the data collected in large locomotive works, where 250 volt direct current dynamos are used. The saving in power effected by the installation of electric transmission amounts to 50 per cent.

In addition to this, the introduction of electrically worked overhead and other cranes has effected an enormous saving in unskilled labour, two overhead travelling cranes alone having dispensed with the services of 80 labourers.

Further savings in money and time are effected by reducing the number of unskilled labourers—in one department—from 40 to 5, and the time for removing finished work at one machine and placing the new piece is reduced from 30 to 5 minutes.

Electric drills and other labour saving devices have also contributed to a large increase in output, and reduction in the number of hands employed.

The cost of electric power at these works, including fuel, engineers and firemen, labour and materials for repairs of power-house, line and motors, and interest and depreciation on the cost of plant, is about 1·2d. per cent on the amount of wages paid.

RELATIVE ECONOMY OF HAND AND ELECTRIC CRANES.—The following facts have been kindly placed at the writer's disposal by the proprietors of large steel works.

A 20 tons hand power overhead travelling crane, formerly used for changing rolls, has recently been converted to work by electric power (3 motors).

Economies.—The time occupied in changing rolls by hand power was 12 hours; 21 men were employed, and the average cost was £7 8s.

Since the electric crane has been employed, the same work has been done in 7 hours, and the average cost is £2 5s. The same crane serves the roll turning tools.

Similar results have been experienced in many other works, but accurate records are very rarely obtainable.

HORSE POWER REQUIRED TO DRIVE MACHINERY.

GROUP SYSTEM.—When using the figures in the following table, it will be well to bear in mind that where power for driving a number of small machines, can conveniently be transmitted from one motor; very much less total power need be provided than would be required if each machine were driven from its own motor.

The machines cannot all be working at full capacity simultaneously (excepting for a very short time during which a sensible overload is of no importance), so that 10 machines, each requiring 1 H.P. could probably be driven by a motor of 5 H.P. without much overload, whereas if one 1 H.P. motor is set to drive two machines, it must sometimes have 100-per cent. overload.

Belt or gear driving.—Direct drive by gear is usually much less satisfactory than driving by belt, and short belts, after one or two adjustments, seem to run almost indefinitely.

MACHINE.	H.P.
Screw-cutting lathe, small, 13½-in. swing (back geared)	0·41
,, ,, ,, ,, 12-in. ,, ,, ,,	0·33
,, ,, ,, ,, 17½-in. ,, ,, ,,	0·867
,, ,, ,, ,, 20-in. ,, ,, ,,	0·47
,, ,, ,, ,, 26-in. ,, ,, ,,	0·462
Facing and turning lathe, large, 80-in. face plate, will swing 108-in., treble geared	0·53
Facing lathe, large, 68-in. swing (treble geared)	0·91
Shaper, small (stroke 4-in., work traverse 11-in.)	0·16
,, ,, (9½-in. stroke by 22-in. traverse)	0·24
,, ,, (15-in. stroke)	0·63
,, large (29-in. stroke by 91-in. traverse)	1·14
Planer, crank (23-in. by 27-in. by 28½-in. stroke)	0·24
Planer (36-in. by 36-in. by 11-ft.)	0·84
,, large (76-in. by 76-in. by 57-ft.)	1·47
Drill press, small	0·62
Slot drilling machine, upright (for 2½-in. diameter slots)	0·41
Drill press, medium	1·24
,, ,, large	1·33
Radial drill (6-ft. swing)	0·53
,, ,, (8½-ft. swing)	0·67
Radial drill press	1·08
Slotter (8-in. stroke)	0·28
,, 9½-in. ,,	0·44
,, 15-in. ,,	0·95
Milling machine, Universal, without overhanging arm	0·28
,, ,, (13-in. cutter head, twelve cutters)	0·66
,, ,, small head traversing (cutter head 11-in. diameter, 16 cutters)	0·18
Gear cutter (will cut 20-in. diameter)	0·28
Boring machine, horizontal, for iron (22½-in. swing)	0·93
Shearing machine, hydraulic	1·52
Plate shears, large (knives 28-in. long, 3-in. stroke)	7·12
Punch press, large (over reach 28-in., 3-in. stroke, 1½-in. stock can be punched)	4.41
Punch and shear combined, small (knives 7½-in. long, 1½-in. stroke)	0·79
Saw, circular, for hot iron (30½-in. diameter of saw)	4·12
Rolls, plate bending (diameter of rolls 13-in., length 9½-ft.)	2·70
Wood planer, 13½-in. (rotary knives, two horizontal and two vertical knives)	4·24
,, ,, 24-in. ,, ,,	4·63
,, ,, 17½-in. ,, ,,	3·03
,, ,, 28-in. ,, ,,	5·00
,, ,, 28-in.	3·20
Wood planer and matcher (capacity 14½-in. by 4¾-in.)	6-91
Saw, circular, for wood (23-in. diameter of saw	3·23
,, ,, ,, 35-in. ,, ,,	5.64
,, band, for wood (34-in. band wheel)	0·96
Mortising and boring machine, for wood	0·49
Boring and mortising machine, for wood, horizontal (drill 4-in. diameter, mortise 8½-in. by 11½-in. long)	3·68

MACHINE.	H.P.
Tenon and mortising machine	2·11
,, ,, ,,	2·73
,, ,, ,,	2·25
Edge moulder and shaper, vertical spindle	2·00
Moulding machine for wood ($7\frac{1}{2}$-in. by $8\frac{1}{2}$-in., horizontal spindle)	2·45
Grindstone, for tools, 31-in. diameter by 6-in. face (velocity 680-ft. per minute)	1·55
Grindstone, for stock, 42-in. diameter by 12-in. face (velocity 1680-ft. per minute)	3·11
Grindstone	1·08
Emery wheel, $11\frac{1}{2}$-in. diameter by $\frac{1}{4}$-in. (saw grinder)	0·56
Punch, double, running light	2·00
Punching both ends 1-in. hole, $\frac{7}{8}$-in. plate, 28 punches per minute each end	5·00
Punch and shear, running light	2.00
Punching hole as above and shearing $\frac{7}{8}$-in. plate, $5\frac{1}{2}$-in. cut, 28 strokes per minute	6·5
Plate bending rolls, running light	5·5
Rolling plate $\frac{9}{20}$-in. thick, 4-ft. 4-in. wide, and 16-ft. 6-in. long, endways on (4-ft. 4-in)	6·9
Rolling, sideways on (16-ft. 6-in.)	12·2
Rolling plate $\frac{11}{20}$-in. by 4-ft. $8\frac{1}{2}$-in. by 21-ft. long, sideways on	19·3
Same rolls lifting and lowering top roll :	
Litfing	8·5
Lowering	7·0
Forcing $\frac{11}{16}$-in. plate down	10·0
Forge fan for 24 fires	10·5
Angle squeezer, running light	0·8
Squeezing	2·5
Wood working machinery :	
Small plane	0·8
Tenoning machine	0·8
Band saw	1·5
Cross-cut saw	2·5
Small circular saw, cutting 6-in. pitch pine, hand fed	6·4
Circular saw, 48-in., sawing 18-in. teak, 6-ft. 6-in. per minute	24·0
Sawing $4\frac{1}{2}$-ft. teak, 25-ft. per minute	17·7
Counter-sinking machine. Actual power taken in counter-sinking	3·5
Rivetting machine, running light	1·6
Rivetting	3·0
Wall planer, taking $\frac{3}{8}$-in. cut, cast iron	5·0
Radial drill, $1\frac{1}{14}$-in. hole, cast iron	5·0
Plate planing machine, running light	0·6
,, ,, ,, reversing light	1·8
,, ,, ,, cutting 1-in. by 14-ft. plate	3·1
Stern frame, boring, cutting	1·75
Shafting, lathe 18-in. centre, running light	0·5
,, ,, One tool cutting $\frac{11}{16}$-in. square cut	1·8
,, ,, Two ,, ,, ,,	2·5
Lathe, 9-in. centre, $\frac{3}{16}$-in. cut	0·6
Angle-cutting machine, running light	1·6
Cutting angle 6-in. by $3\frac{1}{2}$-in. by $\frac{1}{2}$-in.	3·5
Winch, lifting 28-cwt. single purchase, 50-ft. per minute	6·5
Ending machine, running light	1·9
Cutting girder, 18-in. by 7-in.	4·0 to 4·8
Cold saw, running light	2·0
,, Cutting 4-in. by 4-in. angle	4·0 to 4·5
Air compressor, 10-in. by 14-in. cylinder, 50-lbs. pressure	15·0 to 23.5
Portable drill, drilling 1-in. holes	1·5
Hydraulic pumps, three pumps $3\frac{3}{4}$-in. diameter, $4\frac{3}{4}$-in. stroke, 60 strokes per minute, pressure 870 lbs.	38·0
Joiner's shop motor, normal load	14·9 to 22·0
Machines being driven from this motor : One 20-in. plane, one 24-in. circular saw, one 30-in. planing and sand-papering machine.	
Electrical winch, running light	1·2
,, ,, lifting 24-cwt. 16-ft. per minute	5·6

(Mechanical World Pocket Book.)

POWER THAT STEEL SHAFTING WILL TRANSMIT AT VARIOUS SPEEDS.

Revolutions per Minute.	DIAMETER OF SHAFTS.															
	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	9	10
	HORSE POWERS THEY WILL TRANSMIT.															
50	3·3	8·0	15·6	27	43	64	91	125	166	216	275	343	422	512	729	1000
60	4·0	9·6	18·8	32	51	77	109	150	200	259	330	412	506	614	875	1200
70	4·7	11·2	21·9	38	60	89	128	175	233	302	385	480	591	717	1021	1400
80	5·4	12·8	25·0	43	69	102	146	200	266	346	439	549	675	819	1166	1600
90	6·0	14·4	28·1	49	77	115	164	225	299	389	494	617	759	922	1312	1800
100	6·7	16·0	31·2	54	86	128	182	250	333	432	549	686	844	1024	1458	2000
110	7·4	17·6	34·4	59	94	141	200	275	366	475	604	755	928	1126	1604	2200
120	8·1	19·2	37·5	65	103	154	219	300	399	518	659	823	1012	1229	1750	2400
130	8·7	20·8	40·6	70	111	166	237	325	433	562	714	892	1097	1331	1895	2600
140	9·4	22·4	43·8	76	120	179	255	350	466	605	769	960	1181	1434	2041	2800
150	10·1	24·0	46·9	81	129	192	273	375	499	648	824	1029	1265	1536	2187	3000
160	10.8	25·6	50·0	86	137	205	292	400	532	691	879	1097	1350	1638	2333	3200
170	11·5	27·2	53·1	92	146	218	310	425	566	734	934	1166	1434	1741	2479	3400
180	12·2	28·8	56·3	97	154	230	328	450	599	778	989	1235	1519	1843	2624	3600
190	12·8	30·4	59·4	103	163	243	346	475	632	821	1044	1303	1603	1945	2770	3800
200	13·5	32·0	62·5	108	172	256	365	500	665	864	1099	1372	1687	2048	2916	4000
225	15·2	36·6	70·3	122	193	288	410	563	749	972	1236	1543	1898	2304	3280	4500
250	16·9	40·0	78·1	135	214	320	456	625	832	1080	1373	1715	2109	2560	3645	5000
275	18·6	44·0	85·9	149	236	352	501	688	915	1188	1510	1886	2320	2816	4009	5500
300	20·3	48·0	93·7	162	257	384	547	750	998	1296	1648	2058	2531	3072	4374	6000
325	21·9	52·0	101·6	176	279	416	592	813	1081	1404	1785	2229	2742	3328	4739	6500
350	23·6	56·0	109·4	189	300	448	638	875	1165	1512	1922	2401	2953	3584	5103	7000
375	25·3	60·0	117·2	203	322	480	683	938	1248	1620	2060	2572	3164	3840	5468	7500
400	27·0	64·0	125·0	216	343	512	729	1000	1331	1728	2197	2744	3374	4096	5832	8000
425	28·7	68·0	132·8	230	364	544	775	1063	1414	1836	2334	2915	3585	4352	6197	8500
450	30·4	72·0	140·6	243	386	576	820	1125	1497	1944	2472	3087	3796	4608	6562	9000
475	32·1	71·0	148·4	257	407	603	866	1188	1580	2052	2609	3258	4007	4864	6926	9500
5 0	33·7	80·0	156·2	270	429	640	911	1250	1664	2160	2746	3430	4218	5120	7890	10000

NOTES ON SHAFTING AND MACHINERY.

TRANSMISSION OF POWER.—The following memoranda and tables relating to this subject, are taken from the "Practical Engineer Pocket Book" and are, for the most part, compiled from Musgrove's formulæ and tables which are based on actual experience.

STEEL DRIVING SHAFT.—The table on page 252 gives the powers that *steel* line shafts will transmit at speeds varying from 50 to 500 revolutions per minute, and by simple application of the decimal point may be made to answer for speeds ranging from 5 to 5000 revolutions per minute.

The powers given are well within the safe limits of line shafting, and will cause a torsion of less than one degree per foot run. If the shafts are used as prime movers, they should not be required to transmit more than 70 per cent. of the power given in the table.

WROUGHT-IRON LINE SHAFTS—These may be taken as capable of transmitting 70 per cent. of the power of a steel shaft of the same size. In all cases the shaft should be well supported with bearings at suitable intervals. The following table will serve as an approximate guide in fixing on the distance of the bearings apart for shafts carrying a fair proportion of pulleys.

CENTRES OF BEARINGS FOR STEEL DRIVING SHAFT.

Diameter of Shaft in inches	1½	2	2¼	2½	2¾	3	3½	4	4½
Centres of Bearings apart	7ft. 0in.	8ft. 0in.	8ft. 6in.	9ft. 0in.	9ft. 6in.	10ft. 0in.	11ft. 0in.	12ft. 0in.	13ft. 0in.
Diameter of Shaft in inches	5	5½	6	6½	7	7½	8	9	10
Centres of Bearings apart	13ft. 6in.	14ft. 0in.	15ft. 0in.	15ft. 6in.	16ft. 0in.	17ft. 0in.	18ft. 0in.	19ft. 0in.	20ft. 0in.

SHAFTS WITHOUT PULLEYS.—If shafts are simply used for the transmission of power, and do not carry any pulleys, the bearings may be spaced 50 per cent. further apart than in the table given above. On the other hand, extra bearings should be placed near pulleys which transmit much power.

BEARINGS.—Carefully conducted tests have demonstrated that the white metal alloys are preferable to brass or gun-metal for many kinds of bearings.

Those made by Prof. Smith with a journal 2 inches diameter and 2½ inches long, working in Magnolia metal bearings, the load being 3980lbs., the speed 200 revolutions per minute, and the lubricant Scotch mineral oil, gave a co-efficient of friction as low as ·0133.

Babbit metal, and similar alloys, have been largely used and give excellent results, especially under moderate speeds of working; they possess the further advantages of not setting fast when unused (as in hand cranes, winches, etc.), and of being very easily replaced.

SPEED OF MILLING CUTTERS.—For cutters 6in. in diameter and upwards the speed of the circumference of the cutter should be approximately as follows:

Cast-iron	60ft. per minute.	Steel	36ft. per minute.
Wrought-iron	48ft per ,,	Brass	120ft. per ,,

For finishing cuts the speeds nay be increased from 20 to 30 per cent. On the other hand if heavy cuts are being taken, a similar reduction in speed should be made.

FEED OF MILLING CUTTERS.—If there is no great depth of material to cut away, the rate should be approximately as follows:

Cast-iron	1⅝in. per minute.	Steel	½in. per minute.
Wrought-iron	1 in. per ,,	Brass	2½in. per ,,

SPEED OF EMERY WHEELS.—These should have a circumferential speed of about 5,000ft. per minute.

SPEED OF GRINDSTONES.—These run at about 800ft. per minute.

SPEEDS, &c. OF CUTTING TOOLS.—The following table with reference to the angles of tools and the speeds of working largely adopted in this country for different machines and different kinds of work, may be worthy of record :

ANGLES OF TOOLS.—For wood, 30° to 40°; Wrought-iron, 60°; Cast-iron, 70°; Brass, 80°. The angle of relief varies from 3° to 10°. (*Fowler*).

SPEED OF MACHINE TOOLS.

MATERIAL.	SPEED. Feet per minute.	MATERIAL.	SPEED. Feet per minute.
Shearing and punching ...	2	Turning wrought-iron ..	25 to 40
Turning chilled rolls ...	3 to 4	Turning steel	20 to 25
Screw cutting steel ...	7 to 8	Turning gun metal ...	20 to 40
Screw cutting gun metal..	30	Turning soft brass ...	40 to 100
Boring cast-iron cylinder..	10	Turning wood	1000 to 2000
Turning cast-iron ...	15 to 20	Wood moulding cutters ...	3000 to 5000

SPEED OF DRILLS.—The circumferential velocity of the drill should be about 100ft. per minute for cast-iron, and 150ft. for wrought-iron. The following table of revolutions for different sizes of drills for cast and wrought-iron is calculated on this basis.

Diameter of Drill.	Revs. of Drill per Min.		Diameter of Drill	Revs. of Drill per Min.	
	Wrot. Iron.	Cast Iron.		Wrot. Iron.	Cast Iron.
$\frac{1}{4}$	225	150	1	55	37
$\frac{3}{8}$	150	100	$1\frac{1}{8}$	50	33
$\frac{1}{2}$	112	75	$1\frac{1}{4}$	45	30
$\frac{5}{8}$	90	60	$1\frac{1}{2}$	38	25
$\frac{3}{4}$	75	50	$1\frac{3}{4}$	30	21
$\frac{7}{8}$	64	43	2	28	19

Pressure on head of twist drill in pounds requisite to produce proper cut, equals diameter of drill in inches multiplied by 1,500.

SPEED OF SAWS.—Band saws for hot iron and steel run at about 200 to 300 ft. per minute. For wood the speed is about 4,000ft. Circular saws for wood have a circumferential speed of about 9,000ft. per minute. Plain soft iron discs run at a rim velocity of about 12,000ft. per minute, are sometimes used to cut off ends of steel rails, jets of water playing on the circumference of saw.

ALLOWANCES FOR MACHINING vary so widely with the shape and the manner in which the forging is turned out, that hard and fast rules cannot be laid down.

It is often much more economical to pay a higher price for forgings finished close to dimensions, than to pay a lower price and have much work in the machine and corresponding waste of material.

HARDENING STEEL.—The following colour tests, well known to tool smiths, and the approximate temperatures, will be useful for reference if it is desired to construct furnaces to permanently maintain any degree of temperature which experience has indicated as that to be adopted :—

Pale yellow	... ...	430° F	= 221° C
Straw yellow	... ...	460° F	= 238° C
Brown yellow	... ...	490° F	— 254° C
Light purple	... ...	530° F	= 277° C
Dark purple	... ...	550° F	= 288° C
Clear blue	... ...	570° F	= 299° C
Pale blue...	... ...	610° F	= 321° C
Blue (green tint)	... ...	630° F	= 332° C

OIL TEMPERING STEEL by immersing the article, when at a proper temperature, in a bath of oil slightly hardens the steel, and increases its tensile strength, but does not reduce its malleability or make it much more difficult to shape in machining.

FRICTION OF SOLID BODIES.—This in proportion with the weight or pressure acting on the surface, and is independent both of the area of surfaces in contact and of the velocity. It varies with the nature of the surfaces, even of the materials, also with the quality of the lubricant, and with the temperature.

LUBRICANTS.—For heavy pressures the lubricant should be thick to resist being forced out; and thin for light pressures, so that its vicidity may not add to the resistance.—*Fowler.*

TABLE OF FRICTIONAL CO-EFFICIENTS (FOWLER).

SURFACES IN CONTACT.	STATE OF SURFACES.	COEFFICIENT OF FRICTION
Wood on wood or metal ...	Dry	.4 to ·6
,, ,, ,, ...	Greasy	·2 to ·4
,, ,, ,, ...	Lubricated	·1 to ·2
Metal on metal	Wet	·3
,, ,, ...	Dry	·2
,, ,, ...	Greasy	·15
,, ,, ...	Lubricated	·08

NOTES ON GEARING.

PROPORTIONS OF TEETH.—The following expresses ordinary proportons of teeth in simplest terms of pitch, viz.:

Thickness of tooth = ·48 pitch.
Width of space = ·52 pitch.
Height above pitch line = ·3 pitch.
Depth below pitch line = ·4 pitch.

Professor Unwin, however gives the following proportions for pattern moulded wheels as more in accordance with scientific design:

Thickness of tooth...............	$\cdot 47p - \cdot 02$	to	$\cdot 48p - \cdot 03$
Width of space..................	$\cdot 53p + \cdot 02$	to	$\cdot 52p + \cdot 03$
Side clearance.....................	$\cdot 06p + \cdot 04$	to	$\cdot 04p + \cdot 06$
Height above pitch line..... ..	$\cdot 3p$	to	$\cdot 35p$
Depth below pitch line.......	$\cdot 35p + \cdot 08$	to	$\cdot 4p + \cdot 08$
Total height of tooth...........	$\cdot 65p + \cdot 08$	to	$\cdot 75p + \cdot 08$

TEETH OF MAIN SPUR DRIVING WHEELS AND PINIONS.—In the case of large spur driving wheels and pinions transmitting great powers and running at high velocities, such as those used with cotton mill engines, where the power is frequently over 1,000 H.P. and the velocity of the pitch circle upwards of 2,000 feet per minute, Mr. M. Longridge has shown that the proportions, as regards depth of tooth given above, and which represents general practice, are ill-adapted to resist wear and tear, and that, instead of a total depth of tooth equal to about ·7 of the pitch, a depth of about one half this amount is much better calculated to stand the wear and tear of actual work.

STRENGTH OF TEETH.—Exact calculations of the strength of gearing are somewhat complicated. Mr. Box in his work on "Mill gearing," however gives the following empirical formulæ for the strength of wheel-teeth, taking the pitch as a basis of calculation:

P = Pitch of wheel in inches.
W = Width of tooth in inches.
S = Safe load on one tooth in pounds.

Then, $S = P \times 350$.

This is said to allow a factor of safety of 10. In bevel wheels mean diameter and mean pitch must be taken.

SHROUDED WHEELS.—The effect of shrouding is to reduce the actual length of tooth when considered as an overhung beam, and thus to increase its strength. Different forms of teeth are variously affected by shrouding.

With teeth having parallel flanks, shrouding gives an increase of 38 per cent, while radial teeth gain as much as 100 per cent.

MORTISE WHEELS.—Such wheels are usually taken at one-third the strength of cast-iron of same pitch and width. The teeth of mortise wheels are generally made much shorter than iron teeth on account of the wooden cog having to be made much thicker than its iron fellow, so as to insure proper strength. Thus for mortise wheels the height of the wooden cog and its iron fellow above pttch may be $p \times \cdot 25$; the clearance at the end of the tooth may be $\sqrt{p} \times \cdot 125$; while the depth below the pitch line $= (p \times 25) + (\sqrt{p} \times \cdot 125)$. The width of mortise wheels is generally taken at two and half times the pitch.

POWER TRANSMITTED BY GEARING.—The following tables are based on the following rule :

If p = Circumferential pitch in inches.
B = Breadth of wheel in inches.
V = Velocity of pitch line in feet per minute.
HP = Horse power transmitted.

Then

$$HP = p^2 \times B \times V \div 1000 \text{ for cast-iron.}$$
$$= p^2 \times B \times V \div 625 \text{ for cast-steel.}$$

COMPARATIVE PITCHES OF GEARING
DIAMETRICAL AND CIRCULAR.

DIAMETRICAL PITCH.	CIRCULAR PITCH.	DIAMETRICAL PITCH	CIRCULAR PITCH	DIAMETRICAL PITCH	CIRCULAR PITCH
	Inches		Inches		Inches
$\frac{3}{4}$	4·1888	8	0·3927	26	0·1208
1	3·1416	9	0·3491	28	0·1122
$1\frac{1}{4}$	2·5133	10	0·3142	30	0·1047
$1\frac{1}{2}$	2·0944	11	0·2856	32	0·0982
$1\frac{3}{4}$	1·7952	12	0·2618	34	0·0924
2	1·5708	13	0·2417	36	0·0873
$2\frac{1}{4}$	1·3963	14	0·2244	38	0·0827
$2\frac{1}{2}$	1·2566	15	0·2094	40	0·0785
$2\frac{3}{4}$	1·4244	16	0·1963	42	0·0748
3	1·0472	17	0·1848	44	0·0714
$3\frac{1}{2}$	0·8976	18	0·1745	46	0·0683
4	0·7854	19	0·1653	48	0·0654
5	0·6283	20	0·1571	50	0 0628
6	0·5236	22	0·1428	56	0·0561
7	0·4488	24	0·1309	60	0·0524

NOTES ON BELTING.

The tenacity of good leather belt varies from 3,000lb. to 5,000lb. per square inch of sectional area.

THE CO-EFFICIENT OF FRICTION between ordinary belting and cast-iron pulleys is about ·423.

THE THICKNESS OF BELTS varies from 3-16ths to 5-16ths of an inch, or an average of one-fourth of an inch.

TENACITY OF RIVETTING AND LACING.—The ultimate tenacity of good single leather belting may be taken at about 1,000lb. per inch in width. The corresponding strength of a rivetted joint being about 400lb., a butt laced joint about 250lb., and an ordinary overlap laced joint 470lb. It is not customary, however, to allow an effective strain of more than one-fourth the amounts.

HORSE POWER THAT DIFFERENT LEATHER BELTS WILL TRANSMIT PER INCH IN WIDTH AT VARIOUS SPEEDS.

VELOCITY OF BELT PER MINUTE.	KIND OF BELTS.								
	BEST OAK-TANNED BELTS.			BEST LINK OR CHAIN BELTS.					
	SINGLE BELTS.	LIGHT DOUBLE BELTS.	HEAVY DOUBLE BELTS.	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
FEET.	HORSE POWER THEY WILL TRANSMIT.								
100	·15	·21	·27	·13	·15	·17	·20	·24	·27
200	·30	·42	·55	·25	·29	·35	·40	·47	·55
300	·45	·64	·82	·38	·44	·52	·60	·71	·82
400	·61	·85	1·09	·51	·58	·69	·80	·95	1·09
500	·76	1·06	1·36	·64	·73	·86	1·00	1·18	1·36
600	·91	1·27	1·64	·76	·87	1·04	1·20	1·42	1·64
700	1·06	1·49	1·91	·89	1·02	1·21	1·40	1·65	1·91
800	1·21	1·70	2·18	·92	1·16	1·38	1·60	1·89	2·18
900	1·36	1·91	2·45	1·05	1·31	1·55	1·80	2·13	2·45
1000	1·51	2·12	2·73	1·27	1·45	1·73	2·00	2·36	2·73
1100	1·67	2·33	3·00	1·40	1·60	1·90	2·20	2·60	3·00
1200	1·82	2·55	3·27	1·53	1·75	2·07	2·40	2·84	3·27
1300	1·97	2·76	3·55	1·65	1·89	2·25	2·60	3·07	3·55
1400	2·12	2·97	3·82	1·78	2·04	2·42	2·80	3·31	3·82
1500	2·27	3·18	4·09	1·91	2·18	2·59	3·00	3·55	4·09
1600	2·42	3·39	4·36	2·04	2·33	2·76	3·20	3·78	4·36
1700	2·58	3·61	4·64	2·16	2·47	2·94	3·40	4·02	4·64
1800	2·73	3·82	4·91	2·29	2·62	3·11	3·60	4·25	4·91
1900	2·88	4·03	5·18	2·42	2·76	3·28	3·80	4·49	5·18
2000	3·03	4·24	5·45	2·55	2·91	3·45	4·00	4·73	5·45
2100	3·18	4·45	3·73	2·67	3·05	3·63	4·20	4·96	5·73
2200	3·33	4·67	6·00	2·80	3·20	3·80	4·40	5·20	6·00
2300	3·49	4·88	6·27	2·93	3·35	3·97	4·60	5·44	6·27
2400	3·64	5·09	6·55	3·05	3·49	4·15	4·80	5·67	6·55
2500	3·79	5·30	6·82	3·18	3·64	4·32	5·00	5·91	6·82
2600	3·94	5·52	7·09	3·24	3·78	4·49	5·20	6·15	7·09
2700	4·09	5·73	7·36	3·28	3·85	4·66	5·40	6·38	7·36
2800	4·24	5·94	7·64	3·31	3·86	4·73	5·60	6·62	7·64
2900	4·39	6·15	7·91	3·32	3·87	4·78	5·80	6·85	7·91
3000	4·50	6·36	8·18	3·31	3·86	4·75	5·97	7·09	8·18
3100	4·60	6·58	8·45	3·30	3·85	4·73	5·96	7·33	8·45
3200	4·69	6·79	8·70	3·28	3·82	4·71	5·94	7·37	8·73
3300	4·77	7·00	8·86	3·24	3·77	4·70	5·92	7·35	8·88
3400	4·84	7·21	8·96	3·19	3·71	4·64	5·87	7·32	8·86
3500	4·90	7·31	9·06	3·13	3·61	4·50	5·78	7·26	8·80
3600	4·95	7·40	9·16	3·05	3·50	4·37	5·67	7·16	8·73
3700	4·99	7·48	9·24	2·96	3·39	4·26	5·55	7·01	8·58
3800	5·03	7·54	9·29	2·84	3·28	4·15	5·41	6·87	8·41
3900	5·06	7·60	9·34	2·72	3·13	4·02	5·20	6·70	8·27
4000	5·08	7·64	9·37	2·58	2·95	3·84	5·01	6·48	8·04

WOVEN BELTS are very flexible and light in proportion with their capacity for transmitting power. They are also unaffected by changes of temperature, water, steam, chemical fumes, etc., which would deteriorate, if not destroy, leather belting.

Slip on pulley.– They grip the pulley better than leather belts, so that the usual allowance of 2 per cent. for the latter may be reduced to 1 per cent. for woven belts, with corresponding reduction in wear and tear of bearings.

WORKING STRESS OF BELTS.—The following are the effective working stresses allowed for the different kinds and thicknesses of belts referred to in the tables of powers on the preceding page :--

Ordinary single belts, 50lb.			
Light double belts, 70lb.			
Heavy double belts, 90lb.			
Link belts,	3/8in.	thick,	42lb.
,,	1/2in.	,,	48lb.
,,	5/8in.	,,	57lb.
,,	3/4in.	,,	66lb.
,,	7/8in.	,,	78lb.
,,	1in.	,,	90lb.

SPEED OF BELTING.--On ordinary shop line shafts the velocity of the belts varies from 1,000ft. to 1,500ft. per minute. Lathe belts vary from 1,500ft to 3,000ft. per minute.

STRESS ON SHAFTING.—The cross stress on shafting arising from the sum of the tensions on the two sides of the belt may be taken at 90lb. per inch in width.

DIAMETERS AND PROPORTIONS OF PULLEYS..—The diameter of the pulley should not be less than 100 times the thickness of ordinary belts, or 30 times the thickness of link belts.

The ratio between the diameters of the pulleys should not exceed 6 to 1.

The distance apart depends on the ratio. For pulleys having diameters of 2 to 1 the distance between centres should not be less than 8ft.; if 3 to 1, 10ft.; if 4 to 1, 12ft.; if 5 to 1, 15ft.

The convexity of pulleys should be 1/2in. per foot in width.

The width of pulleys should be one-fourth greater than the width of the belt.

Perforating the rim of a pulley assists the adhesion at high speeds.

MAIN DRIVING BELTS.—For the transmission of comparatively large powers in certain cases, as in dynamo driving for example, belts have for some time steadily been growing in favour, but their relative great weight and excessive first cost prevent their adoption in cases where the power to be transmitted is very large and the distance between the centres considerable, as, for instance, in the main drives of cotton mills. In such cases ropes are preferable on many grounds.

CENTRIFUGAL FORCE OF BELTS.—At the ordinary velocities adopted in connection with line shafts, the effect of centrifugal action does not materially affect the power transmitted. At speeds of about 3,000ft. per minute, and upwards, however, the action of this force tends to reduce the amount of power the belt is capable of transmitting. In the table on page 257 the action of centrifugal force is taken into account in fixing the power transmitted.

LINK BELTS.—On account of their greater strength and flexibility link belts are superior to lighter belts at low speeds, and can be used on smaller pulleys. Their open character also permits of the escape of air, and probably assists their adhesion, while their mode of construction renders them of equal strength throughout. At high velocities their greater weight renders them useless in consequence of the action of centrifugal force.

NOTES ON ROPE DRIVING.

ADVANTAGES OF ROPE DRIVING.—Although spur gearing is, theoretically, the most exact method of transmitting velocity ratios, and when well constructed gives also the highest mechanical efficiency, still its practical working is accompanied with so many disadvantages, as compared with rope driving, that the latter method of transmitting power has during the last ten years largely superseded toothed gearing in cotton mills, where smooth and regular turning are points of special importance. The quietness of ropes is a great contrast to gearing. Changes of speed, or variations of power, in any section, can be more easily effected. Breakdowns are more cheaply and quickly repaired, while the larger diameter and greater weight of main driving drums, coupled with their higher velocity, cause them to act with greater efficiency as speed equalisers, and thus ensure more regular turning.

SIZE OF ROPES AND PULLEYS.—The size and number of ropes, as well as the least diameter of pulley, for any given power are points of importance, and should be considered for each case. It is better to use smaller ropes, consistent with not having too many in the space available. There is less internal friction (which is the principal destructive agent) with small ropes than large ones, and hence greater efficiency and endurance. The least size of pulley should, wherever possible, not be less than thirty times the diameter of the rope. Should circumstances render it necessary to adopt a smaller diameter of pulley than this, then the power transmitted should be reduced in the same proportion.

SPEED AND WORKING STRAIN ON ROPES.—The breaking strain of good cotton ropes is about 4 tons or 9,000lb. per square inch, and a proper allowance for working strain is about 300lb. per square inch of sectional area. Of this amount about 20 per cent., or 60lb., is absorbed in overcoming back tension, wedging of rope, &c., leaving 240lb. for centrifugal force, and transmission of power.

STRAIN DUE TO CENTRIFUGAL FORCE.—The strain arising from this cause increases with the square of velocity, and imposes a limit on the speed beyond which it is not economical to go. This limit for cotton ropes is about 4,700ft. per minute. In the following table the effect of this force is taken into account.

LIFE OF COTTON DRIVING ROPES.—The average life of cotton ropes properly put on and well cared for is about 12 years, while some have remained in good order after a lapse of 17 years.

FLY ROPES FOR TRAVELLING CRANES, Etc.—The velocity of ropes used for this purpose ranges from 3,000ft. to 5,000ft. per minute. As these ropes have to bend round pulleys of small diameter thick ropes cannot be adopted, and it is not usual for them to exceed ¾in. in diameter. For the same reason they should not be relied upon to transmit more than 50 per cent. of the power of main driving ropes.

PROPORTIONS OF COTTON DRIVING ROPES AND PULLEYS.

Diamater of Ropes.	Area of Rope.	Weight per foot.	Ordinary Working Tension including Centrifugal Force.	Velocity of Ropes, 4,700-ft. per Minute (their most effective speed.)			Rope Pulleys.	
				Strain due to Centrifugal Force.	Effective Tension.	Power each Rope will Transmit.	Centre to centre of Rope.	Diam. of Smallest Pulley.
Ins.	Ins.	lb.	lb.	lb.	lb.	H.P.	Ins.	Ins.
½	·1963	·081	47	16	31	4·43	⅞	15
⅝	·3067	·125	72	24	48	6·84	1	18
¾	·4417	·184	106	35	71	10·07	1⅛	22
⅞	·6613	·25	144	48	96	13·67	1 5/16	26
1	·7854	·33	190	63	127	18·05	1½	30
1¼	1·2272	·51	294	98	196	27·90	1 13/16	37
1½	1·7671	·74	426	142	284	40·48	2⅛	45
1¾	2·4053	1·00	576	192	384	54·70	2½	52
2	3·1410	1·30	750	250	500	71·10	2¾	60

HEMP AND MANILLA ROPES.—Ropes made of these materials have been tried for driving ropes, but experience shows them to be neither so strong nor so durable as cotton. They are, however, sometimes used with advantage when the velocity does not exceed about 1500ft. per minute.

STRUCTURAL NOTES.

The general information given in the following pages, as well as that to be found elsewhere, may probably be of service when new buildings, or alterations to existing premises, are under consideration.

Consecutive progress.—In this connection, it may not be amiss to direct attention to the importance of arranging business premises, with a view of the work (of whatever kind) proceeding, as far as possible, without re-handling and with minimum exertion of power.

DESIGNS FOR FLOORS.—In preparing these, attention should be given to the sections which will be most economical and convenient, the deflection permissible under the probable maximum live, or moving loads, and the weight of the materials in the floor itself, which is not included in the following table. If flanges are weakened by holes at points where the maximum load is applied, allowance for this should be made in determining the section of girder to be used.

STRENGTHS OF FLOORS.—The following table, published by Mr. T. W. Ward, gives the approximate live or working loads for various classes of buildings :

Attic floors	34 to 56	lbs. per square foot.
Dwelling room floors	56 to 70	,, ,, ,,
Offices, libraries, etc.	70 to 80	,, ,, ,,
Stairs and passages	80 to 90	,, ,, ,,
Work rooms, light business premises, etc. ...	90 to 100	,, ,, ,,
Churches, theatres, ball-rooms, public halls, stores, etc.	100 to 125	,, ,, ,,
Workshops and light warehouses	125 to 150	,, ,, ,,
Warehouses for heavy materials	150 to 400	,, ,, ,,
Heavy machinery	250 to 500	,, ,, ,,

and to these must be added the weight of materials in the floor itself.

DEFLECTION OF GIRDERS.—A slight occasional deflection is sometimes of little importance, but if beams carrying a plaster floor deflect 1/30th of an inch, the ceiling will probably crack, so that, for such purposes, the depth of the girder should not exceed 1/20th of the span.

FIRE-PROOF FLOORS.—A floor constructed of steel girders and six inches of coke breeze cement weighs about 70 lbs. per foot of area of floor, for which allowance must be made if this excellent construction is adopted.

WEIGHTS OF GIRDERS.—Those given in the table at page 213 may be taken as the mean weights per foot, but some variation is inevitable ; this, however, will usually be covered by an allowance of 2½ per cent. over or under the tabulated weights.

TENSILE STRENGTH AND SAFE LOADS.—The data given at page 213 relates to British made girders, and is based on a **breaking weight** of 28 to 32 tons per square inch of section, an **elongation** of 20 per cent. in a length of 8 inches, and **contraction of area** of 40 per cent.

The tensile strengths of imported girders will probably be about 10 per cent less than those given in the table referred to.

DEAD LENGTHS AND STRAIGHTENING.—Girders sawn hot as they come from the mills can usually be supplied within 1-in. to 1½-in. of the lengths required. If they are cold sawn to exact lengths, the extra cost will probably be 6/- to 7/- per ton.

If cold straightening is necessary the cost ranges from 3/- to 5/- per ton.

TRAM LINES IN WORKS.—The saving in time and in the cost of handling materials which is effected by the use of narrow gauge track and suitable trucks is probably much larger than is generally recognised, but it becomes very evident when we consider that if the wages of only one boy at 2/- per day are saved, this amounts to £30 per annum which is equivalent to 10 per cent. on a capital outlay of £300—far more than that would be required to equip many works or industrial establishments where these appliances do not, at present, exist.

Example of saving.—This is furnished in one works where, after the installation of about 700 feet of track and 12 trucks, the wage sheet was reduced by £4 10s. per day and the industrial efficiency greatly increased.

Gauge of track.—It may be well here to direct attention to the remarks at page 3 with reference to intermediate rails to form a double track in works which are provided with the ordinary (4 feet 8½ inches) gauge railway.

Details to be considered.—These consist principally of the under-named :

The gauge of rails and minimum radius of curves to be used.
The weight of rails and type of track, also of switches and crossings.
The maximum load to be carried and best type of truck.
Can turntables be dispensed with ?
Can a steam or electric locomotive be used ?

General information on most of the above-named points and many approximate prices will be found at pages 89 to 109, or the materials best adapted for the purpose will be supplied if the necessary details, including those relating to the above-mentioned points are furnished.

Turn tables.—If these must be employed the type and diameter should be defined, or the distance between centres of track wheels and the nature, dimensions and weight of the maximum load should be stated.

Locomotives.—The approximate tractive capacity and cost of locomotives of the usual type will be found at pages 91 to 96, but if the use of steam power is inconvenient or inadmissible, the work can be done by electric power.

Electric traction.—Electric locomotives are arranged to pick up the current from over-head or underground conductors, or they are constructed to be supplied from storage batteries which require no attention during the day and can be charged at night, or at intervals in working hours when haulage is not required.

These locomotives are extremely simple and easy to maintain, and are economical where current is generated for lighting or other purposes, or can be obtained at moderate cost.

Rolling stock.—This necessarily varies considerably, but for carrying heavy or bulky loads—say exceeding 5 tons—it will be found desirable to use 8-wheeled trucks with double swivelling bogies.

It is scarcely necessary to point out that the trucks should be constructed with special reference to the work to be performed.

GRADIENTS FOR WOOD PAVEMENT.—It is not desirable to use hard wood for pavements with gradients exceeding 1 in 36. If soft wood is used the gradient should not be more than 1 in 30.

GRADIENTS OF SELF-CLEANSING DRAINS.—The flow in ordinary house or soil drains should have a velocity of about 4½ feet per second, but 3 feet per second usually suffices for drains or sewers of 12 to 18 inches diameter.

FLOORS FOR WORKSHOPS AND STORES.—A really good floor which shall be as noiseless and dustless as possible, support heavy weights without tearing or sinking, and not get into hills and hollows, is always a rather large item in the total cost of a building.

A concrete floor about 6 inches thick, costs 4/- to 5/- per square yard and—if very well laid—lasts a long time.

It is regarded by many as easy to repair, but in practice it is not so, because new concrete put in to make good irregularities—however carefully this may be done—never thoroughly combines with the old work, so that it shells off and always presents an uneven surface and a patchy appearance.

A wood plank floor is the cheapest, but it soon becomes dusty and, under heavy wear, is apt to work loose and to wear irregularly, so that in addition to the above-named objections, there is the further one of a rather serious cost of maintenance.

Wood block floor laid on concrete is the most expensive but by far the best and most durable for warehouses, engineering workshops, etc. The writer's experience with all the systems leads him to conclude that wood block floor is the most economical in the long run and the most satisfactory.

Plank and concrete floor.—A good and durable floor, any part of which is easily renewed when worn, consists of a layer of cinders with one of concrete over it, nailing strips being embedded therein to which the floor planking is spiked.

The thickness of the layers are varied from about 12 inches of cinder and 6 inches of concrete for the floor of heavy engineering works, to about half those thicknesses in shops for lighter work, or for warehouses in which loads are fairly evenly distributed.

COMPOSITE BUILDINGS OF STEEL AND CONCRETE.—The rapidity which factory, warehouse and other buildings can be put up under this mode of construction will recommend it in some countries, if not in this.

The framing of the building usually consists of rolled steel channel bars of light section properly tied, all of which can be prepared and delivered ready for erection. These frames are filled in with cement concrete for the outer walls, the inner walls being formed of expanding metal and plaster or of cement blocks (see below).

The columns may be made of rolled steel sections with lattice ties, and surrounded with expanding metal work and plaster facing.

The floors are easily laid in concrete so that the building is—as far as possible—fire-proof.

FIRE-PROOF PARTITION WALLS.—From tests made in the U.S. of America it seems that plaster portions, whether with or without metallic lath netting, disintegrates rapidly under the action of a stream of water when the walls are a high temperature.

But walls built of terra-cotta, or concrete blocks suffered very little damage from the action of water.

CONCRETE WALLS.—The following system has been successfully adopted by one of the leading railways in the United States of America for the construction of extensive Locomotive and Carriage Works, and seems equally suitable for the walls of many warehouse and other buildings.

Composition of Concrete.—The concrete was made of 1 part Cement, 3 parts Sand and 6 parts Cinder.

These were mixed very wet, and puddled with a light wooden rammer to secure even distribution of the materials.

The forms were of yellow pine coated with soft soap to give a smooth surface, and no provision was made for expansion and contraction.

Mixing and Depositing.—Some of the concrete was mixed by hand and some by machine; the former was the most economical where the walls were less than 18 inches thick If the machines were used for this part of the work the cost of mixing was reduced, but that of handling and depositing was increased.—*Engineer.*

FOUNDATIONS IN SOFT OR WATER-LOGGED GROUND.—The appliances adopted for making the foundations for columns, girders, etc. in many of the buildings for the Paris Exhibition of 1900 are similar to those used for pile driving, the driving monkey being replaced by a cast iron cone with chilled point weighing about 1½ tons.

This cone (raised and dropped as in pile driving) penetrates the ground and rapidly makes a hole, in some cases 8 to 9 feet deep, ready to receive the concrete or other material suitable for the foundation required.

Progress is much accelerated by keeping the ground moist during driving; this also tends to solidify the surrounding ground.

FOUNDATIONS FOR TEMPORARY WORK were also made in the manner last named, the hole being filled with loose stones, with or without cement grouting, and covered with an iron plate, or with timber which can be recovered when the temporary structure is removed.

BITUMEN.—A thin layer of bitumen, forming a continuous surface, laid on concrete or a single course of brick-work as a lining for tanks, reservoirs, sewers, culverts, etc. entirely prevents leakage and is equally effective in protecting iron-work, and making bridge decking permanently water tight.

CEMENT CONCRETE PILES.—The advantages claimed for the concrete piles devised by M. Hennebique are, that being formed of steel bars enclosed in concrete, they are easily driven and absolutely indestructable.

The piles are usually 12 inches to 16 inches square, and consist of four steel bars which are laid in the concrete the full length of the pile and project slightly beyond it at each end.

The concrete can be mixed in any of the machines mentioned at pages 29 to 41, so that no special plant is required; and if a simple elastic medium is introduced between the tops of the steel bars and the driving monkey, the pile is put down quickly and without shattering the head. This has been proved with piles driven to a depth of 50 feet, which have successfully withstood a test load of 200 tons distributed over four piles.

Piles which cannot be driven to their full length are sawn off at the height desired.

SUPPORTING POWER OF PILES.—Mr. E. P. Goodrich states, as a result of careful experiments in which he obtained a record of the vertical motion of the pile, the time occupied by this motion, the velocity of the hammer or "monkey" as it strikes the pile, and of pile at each instant of its movement, as well as the compression of the head of the pile from the blow of the hammer, obtains the following results, which he considers closer than any formula excepting Trautwine's.

He finds that the supporting power, in lbs, of the pile is equal to ten times the weight of the hammer, in lbs., multiplied by the height of drop in feet, divided by three times the penetration of the last blow in inches.

Specifications for pile driving.—He recommends that these should contain the following conditions:

Piles shall be driven to such depths that the last blow of a 3000-lbs. hammer falling freely 15 feet shall not produce a penetration greater than one inch, or an equivalent penetration directly proportional to the weight of the hammer. It is believed that such piles will support an ultimate load of within 10 per cent. of 75 tons.

The formula deduced from the foregoing is $\frac{3000 \times 10 \times 15}{1 \times 3} = 66.96$ tons.

CRUSHING LOADS ON ROLLED STEEL STANCHEONS OR COLUMNS, the ends being flat and firmly fixed and the loads equally distributed.

Dead loads must not exceed one-fifth, or **Live loads** one-seventh of those tabulated.

SECTION.	4 FEET	6 FEET	7 FEET.	8 FEET.	9 FEET.	10 FEET.	11 FEET.	12 FEET.	14 FEET.
	TONS.	TONS.	TONS.	TONS.	TONS.	TONS.	TONS.	TONS.	TONS.
3 × 3	33·1	29·4	27·4	25·5	23·6				
4 × 3	35·4	31·2	29·0	26·8	24·7	22·7			
5 × 3	37·7	33·0	30·6	28·1	25·8	23·7			
5 × 4½	74·0	69·7	67·2	64·5	61·7	58·9	56·0	53·2	47·6
6¼ × 3⅛	50·6	44·5	41·1	37·9	34·8	31·9	29·2	26·8	22·5
6 × 5	95·7	90·5	88·6	85·7	82·7	79·5	76·3	73·0	66·6
7 × 3¾	53·4	47·7	44·4	41·8	38·5	35·6	32·9	30·3	25·8
8 × 4	78·5	72·0	68·3	64·5	60·6	56·9	53.2	49·7	43·2
8 × 5	112·6	107·1	103 7	100·1	96·3	92·4	88·5	84·5	76·7
8 × 6	121·9	119·5	116·7	113·7	110·5	107·0	103·5	100·0	92·5
9 × 7	221·7	215 7	212·4	207·8	203·3	198·5	193·4	188·2	183·4
9¼ × 4	81·7	74·2	70·0	65·8	61·5	57·3	53·4	47 6	42·8
9½ × 4½	92·4	86·5	83·0	79·4	75·6	71 7	68·0	64·2	57·2
10 × 4½	98·9	92·6	88·9	84·9	80·9	76·8	72·7	68·7	61·1
10 × 5	116·9	111·1	107·4	103·5	99·4	95·1	90·8	86·4	78·1
10 × 6	176·5	169·6	165·4	160·8	156·0	150·8	145·5	140·1	129·2
12 × 5	151·6	142·2	136·7	130·8	124·8	118·6	113·1	105·5	95·0
12 × 6	188·4	181·6	177·3	172·6	167·6	161·3	156·7	151·3	140·0
12 × 6½	242·6	234·1	228·8	223·1	216·9	210·3	203·6	196·7	182·6
13 13/16 × 5½	192·7	185·1	179·4	173·3	166·7	160·0	153·2	146·4	133·0
15¾ × 6 3/32	268·5	257 3	250·4	242·0	235·0	226·9	218·4	209·7	192·7

(*Measures*).

BRICKS AND BRICKWORK.—Bricks should be free from cracks, flaws or lumps, especially lumps of lime, and should not absorb more than one-sixth of their weight of water.

Brickwork should be well bonded, no joints between bricks coming in line either lengthwise or across the work.

Stock bricks measure 9-in. × 2¼-in. and the average weight is about 6¾-lbs.

1000 bricks stacked = 56 cubic feet. 18 bricks=1 cubic foot and weigh about 120-lbs.

A Rod of brickwork contains 4300 (235 cwts.) bricks and 71 cubic feet of mortar, and the weight is about 15 tons.

A cubic foot of brickwork requires 15 bricks when set in mortar, and weighs about 120-lbs.

A square foot of wall, single thickness, requires 6¾ bricks, or 13½ for one brick thick.

Materials in a rod of brickwork.—These consist of 1⅓ cubic yards of chalk lime and 3 loads (cubic yards) of sand, or its equivalent; or 1 cubic yard of stone lime and 3⅓ cubic yards of sand; or 36 bushels of cement and 36 bushels of sharp sand.

Number of bricks in a piece of work.—Cubical contents in feet × 15=number of bricks used.

Bricks in compression.—The crushing weight has been found to vary from about 500lbs. to 10,000-lbs., and even more, per square inch, but the safe permanent load allowed usually ranges from 100-lbs. to 200-lbs. per square inch.

The result of a number of carefully conducted tests on brick piers show that the resistance to crushing is largely influenced by the nature and properties of the mortar, or cement, used: piers built with lime mortar cracking under a load of 833-lbs. whilst similar piers built with Portland cement and sand have withstood more than twice the above-named load.

ARTIFICIAL STONE FOR PAVING AND OTHER PURPOSES.—Goo paving slabs or "flags" are produced by mixture, in proper proportions, of cement, sand and a little water, with granite chippings, clean gravel, stone quarry refuse or destructor, or furnace slag.

Very little machinery was employed, formerly, in their production, but the steady and by no means unimportant increase in demand, and the difficulty in obtaining a supply of sufficiently skilled labour has (in this, as in other branches of manufacture) led to the introduction of machinery whereby the labour of one man suffices to turn out thirty or more blocks per hour well finished and of thoroughly reliable quality, but as mentioned further on, it is better to limit the number to twenty-five or thirty per hour.

Process of manufacture.—Apart from the appliances (which may or may not be required) for thoroughly cleansing the materials, stone breakers and screens (see pages 181 to 184) are necessary for classifying in suitable sizes, and elevators or conveyors (referred to at pages 222 to 224) for delivering the sized materials to the concrete mixing machine.

Almost any of the machines illustrated and described at pages 29 to 41 may be used, but none give better results than that represented by Fig. 5017.

Whether the materials, including cement, shall be measured and fed into the mixer automatically, or in accurately ascertained proportions, is largely a matter of convenience, but experience indicates that the variations in proportions which almost inevitably occur in feeding automatically, may lead to inequalities in the proportions of materials delivered to the mixer, involving, perhaps, waste of cement, or decreased strength of finished products. Some remarks on this subject will be found at page 30.

The charge fed into the mixing vessel with a small quantity of water is delivered, after 12 to 20 revolutions, completely mixed and ready for consolidation by hydraulic pressure.

Hydraulic press.—This most complete labour-saving machine consists of a massive base and head carried on steel columns which support the pressure cylinder and ram. A block suitable in size and shape for the object to be produced is attached to the bottom of the ram and this operates on a mould, which has been filled with concrete for a new block, during the time that the preceeding block has been kept under pressure and is being removed. The tables are moved by hydraulic appliances, so that one man easily manipulates the press and fills and discharges the moulds. The presses are entirely self-contained and do not require expensive foundations.

Hydraulic pressure plant.—The pumps, accumulator, intensifier and the steam, gas or oil engine, or electric motor, can be fixed where convenient, but as a rule, power for driving the pressure pumps is supplied from the motor which drives the concrete mixer and accessory installations.

Arrangement of plant.—Considerable economies may be effected by judicious arrangement of the concrete plant and that for transferring the finished products to the soaking tanks, where they remain a longer or shorter time according to the nature and quality of the products.

Output of plant.—The same presses are employed whether the articles manufactured are paving slabs, balustrades, architectural mouldings, or other articles, and can be tinged in almost any colour, but the quantity of paving blocks made so far exceeds other products, that they are adopted as the standard for output.

It may be well to mention that the presses are capable of turning out much more than the above-named 25 or 30 slabs per hour, but experience shows that the quality is greatly improved by limiting the output to about that number in order to obtain a sufficiently prolonged exposure to pressure.

Size of paving slabs.—Unless otherwise instructed the presses are adapted for making blocks 3-ft. by 2-ft. 6-in., 2-ft. 6-in. by 2-ft., and 2-ft. by 2-ft., and of any thickness between about 2-in. and 3-in.

Price of paving slabs.—The best quality of slabs made of granite chippings and the highest quality of Portland cement are usually to be obtained at the rate of about 6d. per superficial foot, for slabs 2-in. thick.

NOTES ON LIGHT.

INTERCEPTION OF LIGHT BY GLASS.—It has been ascertained by experiment that the volume of light transmitted through different kinds of glass decreases in the following ratios :—

British polished plate glass ¼-in. thick	13 per cent.
Sheet glass, 32 oz.	22 ,,
Rough cast plate glass ¼-in. thick	30 ,,
Rough rolled plate glass ¼-in. thick, four flutes in an inch	53 ,,

—*Engineer.*

LIGHTING LARGE AREAS.—If neither gas or electric light is available for the temporary or permanent lighting of large areas in the open air, in factories or other buildings, probably one of the methods of burning kerosene or similar oil in conjunction with pneumatic pressure will be the most convenient and economical. The oil incandescent light is perhaps the best of these, being perfectly pure, cleanly and quite easy to instal.

ELECTRIC LIGHT.—As pointed out elsewhere, if current is provided for motive power, the additional cost of current required for lighting is so small and the superiority over all other modes of lighting is so marked, that probably there will usually be little hesitation in adopting it.

Cost of installation.—Information on this subject with relative cost of different types of generators will be found at pages 238 to 241.

OIL INCANDESCENT LIGHT.—This light, Kitson's system, is produced by vapourising kerosene or one of the high rectified hydro-carbon oils in minute quantities.

This vapour, used in conjunction with a Bunsen burner and an incandescent mantle, produces an extremely steady and brilliant light at very small cost, and so pure that it is successfully used for photographic and artistic purposes, as well as for general lighting.

Mode of production.—The supply of oil for one or for a number of lamps is stored in a steel reservoir of the necessary capacity, and delivered under pneumatic pressure by tubing to the vaporiser and burner. The reservoir is complete with all necessary fittings, and may be placed in a cellar, or wherever convenient.

Comparative cost.—A series of carefully conducted tests show that, including renewals and attention, 1000 candle-power oil incandescent light costs 0·8 pence per hour.

The cost of incandescent gas and electric light of 1000 candle-power, taken under the conditions above referred to, was respectively 1·7 pence and 2·7 pence per hour.

The cost of installation for oil incandescent lighting is very moderate whether for constructional, manufacturing or domestic purposes, but as the present remarks apply principally to the former the following indications of cost will probably suffice.

The prices of lamps of 1000 candle-power, with globe and fittings ready for fixing, range from £8 to £10 each.

Reservoirs vary in capacity and price, but one to supply one lamp of 1000 candle-power for 30 hours (or two lamps for 15 hours), complete with fittings, costs about ... £14

A contractor's lamp, with post and tripod, reservoir and outfit, costs about ... £22

Street lamps, with column and complete outfit, will probably cost, each, from £25 to £30

WELLS LIGHT.—This system burns refined mineral oils such as kerosene, etc. and, being very portable and easy to handle, has been largely used during the construction of railways, dock and large buildings of all kinds, as well as in premises where a powerful light is occasionally required.

PORTABLE STANDARD LAMPS are usually from 1500 to 3500 candle-power and are entirely self-contained. The supply of oil is carried in a cylindrical reservoir built of steel plate, and fitted with pump for charging it, and for producing the pneumatic pressure required to supply oil to the lamp.

A tubular standard is fixed in the top of the reservoir which carries the lamp and all appliances for controlling the flow of oil.

PRICES OF STANDARD LAMPS.

Candle power of lamp	1500	2500	3500
Length of flame ... ... inches	18	24	36
Consumption of oil per hour ... ... gallons	¾	1¼	2
Price of portable lamp complete	£15 10	£16 10	£17 15
Extra burners ... ... each	30/-	35/-	40/-

Packing for shipment and delivery f.o.b. costs about 5 per cent.

PORTABLE OR FIXED LAMP POSTS. – These are of wrought iron and can be used in connection with the reservoirs and lamps above described, the lamps being provided with flexible tube connections and appliances for regulating the height of lamp up to 20 or 25 feet, or for lowering to ground level for cleaning, etc.

The price of post, flexible tube and accessories is £7.

SMALL PORTABLE STANDARD LAMPS of 500 candle power, weigh only about 30 lbs., and are useful for moving where special lighting is required, and, like the larger lamps, have handles for that purpose.

The price of a 500 candle power lamp is ... ... £7 10s.
Extra burners cost 30/- each.

KEROSENE HAND LAMPS, which cost only a few shillings each, should be included in the equipment for prospecting or similar expeditions, works, factories, etc.

LIGHTING FOR WORKS AND BUILDINGS.—The experience gained in the construction of the Forth Bridge fully established the value of the electric light whether for outside or inside illumination and for permanent or temporary works.

The cost of installation is so small an item in the total cost of plant for works of any magnitude, the entire absence of heat or smell inseparable from oil or other lamps, and the extreme flexibility of the electric system are all strongly in favour of its adoption.

The Lamps employed on the Forth Bridge works were the usual 16 candle power incandescent for interiors, and arc lamps of 1500 to 2000 candle power for yards and similar lighting.

The relative advantages of electric and oil, or other modes of lighting, were never more prominent than in the perfect illumination by electric light of the air-chambers and shafts of the pneumatic caissons, with entire absence of contamination of air by unconsumed products which is so exhausting to men when working under pneumatic pressure.

The Lucigen light, costs little for installation and maintenance and is often used with great advantage. The principal drawback to it is, that unconsumed oil is sometimes carried away by a high wind to the detriment of stagings or anything on which it may be deposited.

ACETYLENE LIGHT.—The illuminating power of this light is 15 times higher than that of coal gas, with far greater purity and brilliance. The plant for its production is compact and presents no difficulties in erection or attention, and it is claimed that Acetylene can be produced with safety in small installations for private use, or in large ones for public supply.

Cost of Acetylene —One cwt. of Carbide of Calcium produces about 560 cubic feet of Acetylene ; this will supply 130 lights each of 15 candle power for ten hours, and assuming the cost of carbide to be as high as 30/- per cwt. the cost per light is about one farthing per hour, or approximately the same as coal gas at 3/- per 1000 cubic feet, or electric light at 3d. per unit.

Installations.—The apparatus comprises the generator, a holder and a purifier, with the necessary pipe connections between them, the main pipe for distribution being coupled to a nozzle on the purifier.

Producing capacity.—The quantity made at one operation will supply the number of burners given in the following table, all of 15 candle power and alight during 6 hours; the duration of supply, of course, varies in proportion with the greater or less number of lights, or hours.

PRICES OF ACETYLENE LIGHTING PLANT.

Number of lights (15 c.p.) supplied...	25	50	100	150	200	500	1000
Duration of supply ... hours	6	6	6	6	6	6	6
Price of installation ready for erection	£28	£43	£75	£100	£130	£225	£430

POWER AND FUEL.

EFFICIENCIES OF STEAM, GAS, AND OIL ENGINES.—Mr. Brian Donkin finds that :

The best steam engine consumes 196 British thermal units per indicated horse power, giving an efficiency of 21¾ per cent.

The best gas engine consumes 158 B.T.U. or equal to 27 per cent.

The best oil engine 124 B.T.U. which is equal to 34 per cent.

The best record appears to be 1-lb. of coal under the boiler of a steam engine using super-heated steam, and ¾-lb. of anthracite coal in the gas producer of a gas engine.

GAS OR OIL ENGINE INSTALLATIONS.—It is claimed that with gas at 2/6 per 1000 cubic feet, or oil at equivalent price, a gas or oil engine coupled direct to the dynamo spindle will produce current at a cost of about 1½d. per Kilowatt hour, including all charges for attendance, maintenance, and depreciation.

The obvious advantage of this system is that the engine is started only when electric light or power is required, that it requires no attention when running, and working expenses cease when the engine is stopped.

DETERIORATION OF BOILERS.—Without attempting to deal with this large subject in detail, it may be well to mention some of the points which should have careful attention.

Corrosion of Shells.—This is nearly always due to dampness caused by, perhaps, quite minute leakage, or by defective drainage, this evil being frequently exaggerated by an excessive and unnecessary thickness of brickwork on which the boiler rests, leaving that portion inaccessible for examination.

A surface of 4 or 5 inches need never be exceeded, and this should consist of fire brick blocks set in fire clay, care being taken to leave as much access to the shell as possible. Lime mortar, which, when moist, acts most prejudiciously on the shell plates should never be used.

Longitudinal Seams.—These should be above the brickwork side setting, to admit of periodical examination and such attention as may be required.

Grooving and Internal Corrosion.—The former is almost invariably traceable to defects in construction, especially to staying. In some cases it is due to a lack of rigidity, but in many more, to too great rigidity.

Numerous cases could be cited in which this has been induced transversely by the dilation of the crown in vertical boilers, and longitudinally in boilers of the locomotive and other types. The latter is usually due to unequal expansion and contraction, very often caused by contact with too large a mass of brickwork.

COST OF STOKING AND CLEANING LAND BOILERS.—It has been found that the cost of stoking and cleaning factory and similar boilers, agregating about 1000 horse-power, is about 7s. 6d. per horse power per annum.

The cost is divided into 4s. per horse power per annum for stoking, and 3s. 6d. for cleaning.

WATER SUPPLY FOR BOILERS AND CONDENSERS.—There has been a tendency in recent times, no doubt largely due to the increasing use of higher steam pressures

and compound engines, to give far less consideration to the quantity, quality and cost of water supply than to convenience in location for fuel supplies and distribution of power.

Quantity of Water.—Even if provision is made for quite double the quantity of water required for a guaranteed consumption of steam, by the time all the subsidiary plant gets to work, there will probable be some leakage in pistons, valves, etc. to say nothing of possible incrustation in boilers and wetter steam at the engines, so that the guaranteed (say) 15-lbs. of steam per indicated horse power per hour, becomes 20-lbs. or more and much expense is incurred in providing the needful larger supply.

Quality of water.—Whether the generally accepted statement that the effect of scale $\frac{1}{16}$ of an inch thick, is to increase consumption of fuel, 15 per cent. $\frac{1}{4}$-inch. 60 per cent. and so on be correct or not, it is certain that scale deposit in boilers does increase consumption of fuel, and as cheap engine power cannot be obtained without all possible economies in fuel, it would seem that this matter deserves more consideration than it sometimes receives.

FIRING STEAM BOILERS.—Economy in consumption of fuel can only be attained by maintaining a uniform and proper thickness of fire, a thick fire being necessary for high furnace temperature, and this of course, involves firing at regular intervals if the consumption of steam is uniform and continuous.

Heavy stoking at long intervals causes waste of heat by lowering the furnace temperature and allowing gases to pass unconsumed to the chimney.

CALORIFIC VALUE OF FUELS.—This is given in the following tables (Hutton) together with their general characteristics :

WEIGHT, BULK, AND BURNING QUALITIES OF COAL.

Description.	Weight per cubic feet of loose Coal heaped.	Bulk of 1 ton of loose Coal heaped.	Draught required.	How it burns.	Quantity of Smoke.
	lbs.	cub. ft.			
Anthracite	58·2	38·4	Quick	Difficulty	None
Welsh Coal	52·1	43·2	,,	Free and clear	Little
Newcastle	50·3	45·5	Ordinary	Quickly	Large
Lancashire	48.6	46·0	,,	,,	,,
Derbyshire	46·8	47·4	Moderate	,,	,,
Staffordshire	47·0	47·5	Ordinary	,,	,,
Yorkshire	47·6	47·0	Brisk	,,	,,
Scotch	49·2	43·0	Ordinary	,,	Very large

WEIGHT OF ONE CORD OF KILN-DRIED WOODS AND THE EQUIVALENT WEIGHT OF COAL OF AVERAGE QUALITY.

Description.	Approximate weight of one cord.	Weight of Coal that one cord of Wood is equivalent to in evaporative power.
	lbs.	lbs.
English Oak	3850	1560
Ash, Beech, and Thorn	3520	1420
Red Oak, Hard Maple, and Walnut	3310	1340
Apple, Pear, Cherry, and Plum	3140	1260
Birch, Elm, and Hazel	2880	1190
Chestnut and Yellow Pine	2520	1130
Pitch Pine, Alder and Poplar	2130	1050
Willow, White Pine, or Deal	1920	970

LIQUID FUEL FOR STEAM BOILERS.—Appliances invented by Mr. Holden, M.Inst.C.E., for burning almost any kind of petroleum, shale or gas tar oil, alone or in any combination, is attached, at small cost, to locomotive, Cornish or other type of boiler without alteration to the furnace or fire-box, so that ordinary fuel may at any time be used.

The oil feeding appliances are manipulated as easily as an injector and the results of extended tests show that boilers which evaporate only 8-lbs. of water per 1-lb. of coal, evaporate 14-lbs. of water with 1-lb. of oil fuel.

Steam is raised very rapidly, the boiler power is largely increased and combustion being complete, there is an entire absence of smoke, ashes or clinker. The saving in weight and storage room is also considerable.

COAL.—The following table *(Percy)* illustrates the stages of gradual change from wood or decayed vegetable matter to anthracite.

	C.	H.	O.	Disposable. H.
Wood (mean of several analyses)	100	12·18	83·07	1·80
Peat (,, ,, ,,)	100	9·85	55·67	2·89
Lignite (,, fifteen varieties)	100	8·37	42·42	3·07
Ten-yard coal, South Staffordshire	100	6·12	21·23	3·47
Steam coal from the Tyne	100	5·91	18·32	3·62
Pentrefelin coal, South Wales	100	4·75	5·28	4·09
Anthracite, Pennsylvania, U.S.	100	2·84	1·74	2·63

It will be noted that the proportion of carbon relatively increases, whilst the proportion of hydrogen and oxygen relatively decreases; and that, except in the case of anthracite, there is an increase in the disposable hydrogen.

CONTENTS OF COAL DEPOSITS.—An approximate estimate may be made of the quantity of coal which may be expected to be obtained from a given area, by taking the number of English acres and reckoning that a thickness of each 1 inch of coal will yield about 100 tons of coal for each acre. As an acre is about 4000 square metres and 1 inch about 25 millimetres, it follows that practically the same result is obtained by 4000 × 025 = tons of coal 100, and that each acre or 400 square metres of a seam 4 ft. thick will yield 4800 tons of coal.

This mode of estimating leaves about 25% for faults and loss in working, which is usually a sufficient margin for these contingencies.

But the accuracy of the estimate depends largely on the specific gravity of the coal, which varies from about 1.12 for some lignites to 1.61 for some anthracites, whilst the specific gravity of bituminous coal ranges from 1.25 to 1.3; the former figure having been used as the basis for the foregoing method of approximate estimate.

Evidently this rule applies equally to ores by merely altering the figures for specific gravity.

GAS COAL.—A good gas coal should yield 10,500 cubic feet of 16-candle gas and a very good gas coal 10,500 cubic feet of 17-candle gas. The sulphur should not exceed 1 per cent, nor the ash 5 per cent. The yield of coke of good quality should be from 65 to 70 per cent. As is well known the cannel coals are the most valuable for gas making.

COKE.—The best coke is obtained from bituminous coal of the "caking" variety. It is clean, crystalline and porous, and is formed in columnar masses; the colour is a steel grey, with a metallic lustre and a metallic ring when struck.

If the coal possesses less than 3 per cent of free hydrogen it is unfit for coke making, at least 4 per cent is required to produce good coke. If rough small coal is used for coke making, the difference in the quality of coke made from washed and unwashed coal is very largely in favour of the former.

The composition of Durham coke varies within the following limits—Carbon, 85 to 92 per cent; sulphur 0.25 to 2.3 per cent; ash 4 to 12 per cent; whilst the purest coke known contains carbon 97.6 per cent; sulphur 0.85 and ash 1.55 per cent.

DEPRECIATION OF MACHINERY.—Some authorities hold that if machinery is well maintained out of revenue, an all-round charge of five per cent. per annum suffices to cover depreciation and wear and tear. Very much depends on the class of machinery and the manner in which it has been upheld, as will be seen from the following table which was based on experience with rather antiquated machinery.

Rate per annum for	Depreciation.	Wear and Tear.	Total.
Engines	6 %	3 %	9 %
Boilers	10 %	3 %	13 %
Machine tools	7½ %	3½ %	11 %
Shafting, gearing, etc.	4 %	2½ %	6½ %
Driving belts	—	45 %	45 %

NOTES ON RAILWAYS.

EXPANSION AND CONTRACTION OF RAILS.—The results obtained by experiment in the U.S.A. on rails of ordinary sections and 30 feet long are as follows :

Weight of rails ... ... lbs. per yard	56	75	85
Contraction under temperatures from 5° above to 20° below zero, inch	3/16	1/8	1/10
Expansion under temperatures from 5° above to 70° above zero, inch	1/12	1/16	1/17

COST OF MAIN LINE RAILWAYS IN GREAT BRITAIN.—The capital cost is stated by Sir Douglas Fox in his Presidential Address (Inst. C.E.) to range from about £630,000 per mile in London, to an average of £52,378 per mile in the United Kingdom, and taking a fairly representative section of one of the main lines, outside the Metropolis, and constructed in recent years, as an example, the percentages of the cost of about £4 ,000 per mile work out somewhat as follows:

Land and compensation	10 per cent.
Fencing	1½ ,,
Earthworks	24 ,,
Tunnels	12 ,,
Viaducts	8 ,,
Bridges for roads	9 ,,
Accommodation works	2 ,,
Culverts and drainage	5 ,,
Permanent way, including ballast, main line	11½ ,,
Sidings	3 ,,
Junctions and signals	1 ,,
Stations, including buildings (roadside only)	6½ ,,
Contingencies, including parliamentary, administration, legal and engineering expenses	6 ,,
Maintenance	½
	100

APPROXIMATE COST OF INDIAN AND COLONIAL RAILWAYS.—The average cost of railways in India is stated by the same authority to be £8,127 per mile, and £3,200 to £3,500 per mile in South Africa and South America, or with equipment, £4,000 per mile—"a rate at which, in new countries and under fairly normal conditions, railways can be provided suitable for a speed of 30 miles per hour, and for heavy trains."

AMERICAN AND ENGLISH RAILWAYS.—"The railways of the United States (1899) aggregate about 186,000 miles in length, with a cost of about £11,000 per mile, and gross earnings of £1,300 per mile.

In Great Britain there are about 22,000 miles of railway, which have cost about £45,000 per mile, and earn about £4,000 per mile.

This relation of the earning capacity of English and American railways is very generally overlooked, but it has a very powerful influence upon statistics which have reference to dividends and financial returns."—*The Engineer.*

ROAD METALLING, 6 inches thick and 10 feet wide, requires about 1·7 cubic yards of material for each yard forward.

PERMANENT WAY MATERIALS.—The following weights are given as sufficiently accurate for approximate estimates of the quantities required for double track railways of British main line type :—

Weight of rails, lbs. per yard × $3\frac{1}{7}$ = Tons per mile.

,, chairs, about	152 tons per mile.
,, spikes, ,, ...	9 ,,
,, fish plates, about	14 ,,
,, fish bolts and nuts, about ...	4 ,,

COST OF LABOUR IN WORK OF CONSTRUCTION.—This unknown quantity (in the absence of accurate information) is often regarded as perplexing, but the writer has invariably found that, in estimating the cost of labour in carrying out works in any country, the practice of the late Mr. Brassey was singularly accurate, even when the pay of natives employed on earth-works did not exceed 1/- per day, and that of erectors, etc. was not much more.

Mr. Brassey found that the total cost of labour for completing a given quantity of work—irrespective of local rates of wages—so nearly equalled the amount the same work would have cost if carried out in Great Britain, that he adopted average British prices for labour as standard rates when estimating the cost of works to be executed in all parts of the world.

The explanation of this apparent anomaly is that the British workman gets through far more work without the expensive supervision and incidental expenses which must be incurred where the native who—individually—does so little, is employed.

RAILWAY MAINTENANCE.—A singular confirmation of the experience just referred to is obtained by comparing the labour charges for railway maintenance respectively in Russia and in the United States of America.

Cost of maintenance.—In Russia, the number of men employed is 17·2 per mile of line working. The average rate of pay is £42 5s. per man per annum, and the total cost is £581 8s. per mile per annum.

In the United States, the number of men employed is 4·95 per mile of line working, and the total cost is £557 8s. per mile per annum.

We thus see that the cost of maintenance is practically equal, notwithstanding the large difference in the rates of pay.

THE WORLD'S RAILWAYS.—The aggregate capital invested in the world's railways is £6,532,339,200 of which no less than £3,634,022,800 has been invested in 162,225 miles of European railroads, which have an average capital of £23,918 per mile; while the average of 263,356 miles in the other parts of the world is £11,006 per mile. As there are 65,000 miles whose capital is not reported, we are safe in assuming that the world has £7,200,000,000 invested in its railways.—*Engineer.*

GAUGES OF RAILWAYS.

The following table of gauges of main line railways in operation is compiled from information, for most of which the writer is indebted to the Railway or Government Officials of the respective countries.

The large figures (thus **1-m. 435**) always indicates that more miles of this than of the other gauge, or gauges, are operated in the country referred to.

Small local, Funicular and private lines are not recorded.

European Railways.

Great Britain—4-ft. 8½-in. and 2-ft.

France—1-m. 435, 4-ft. 8½-in. and Metre.

Germany—1-m. 435.

Hungary—1-m. 435 and Metre.

Holland—1-m. 435.

Norway—1-m. 435, 1-m. 067 and 0-m. 750.

Denmark—4-ft. 8½-in.

Turkey in Europe—4-ft. 8½-in.

Ireland—5-ft. 3-in. and 3-ft.

Russia—5-ft.

Austria—1-m. 435 and Metre.

Italy—1-m. 435 and Metre.

Belgium—1-m. 435 and Metre.

Sweden—1-m. 435, 1-m. 188 to 0-m. 600.

Switzerland—1-m. 435.

Greece—4-ft. 8½-in.

Australian and Canadian Railways.

Queensland—3-ft. 6-in.

Victoria—5-ft. 3-in. and 2-ft. 6-in.

West Australia—3-ft. 6-in.

Tasmania—3-ft. 6-in.

New South Wales—4-ft. 8½-in.

South Australia—5-ft. 3-in. and 3-ft. 6-in.

New Zealand—3-ft. 6-in.

Intercolonial Railways—5-ft. 3-in. to 3-ft. 6-in.

QUEENSLAND TO ADELAIDE.

Queensland (Brisbane to Jennings)	Gauge 3-ft. 6-in.,	distance	233 miles.
New South Wales (Jennings to Albury *via* Sydney)	,, 4-ft. 8½-in.	,,	876 ,,
Victoria (Albury to Serviceton *via* Melbourne)	,, 5-ft. 3-in.	,,	477 ,,
South Australia (Serviceton to Adelaide)	,, 5-ft. 3-in.	,,	196 ,,
		TOTAL	1782 miles.

Canada—4-ft. 8½-in. and 5-ft. 6-in.

Nova Scotia—4-ft. 8½-in. and 5-ft. 6-in.

NORTH AND CENTRAL AMERICAN RAILWAYS.

United States of America—4-ft. 8½-in. and 3-ft.

Guatemala—3-ft. 6-in.

Venezuela—Metre and 0-m. 609.

Mexico—1-m. 435 and 0-m. 914.

Costa Rica—Metre.

Cuba—4-ft. 8½-in.

SOUTH AMERICAN RAILWAYS.

Brazil—3-ft. 6-in., 5-ft. 3-in., Metre, 3-ft.

Argentina—5-ft. 6-in., 4-ft. 8½-in., Metre.

Chili—5-ft. 6-in., Metre, 2-ft. 6-in.

Paraguay—5-ft. 6-in.

Uruguay—4-ft. 8½-in.

Peru—4-ft. 8½-in.

Bolivia—2-ft. 6-in.

Nitrate Railway—4-ft. 8½-in.

AFRICAN RAILWAYS.

Egypt—4-ft. 8½-in., 3-ft. 6-in.

Natal and South Africa—3-ft. 6-in.

Congo—0-m. 765.

Sierra Leone—2-ft. 6-in.

Soudan—2-ft. 6-in.

Rhodesia—3-ft. 6-in.

Lagos—3-ft. 6-in.

Sekondie-Coomassie—3-ft. 6-in.

INDIAN AND ORIENTAL RAILWAYS.

British India—5-ft. 6-in., Metre, 2-ft. 6 in.

Burma—Metre.

China—4-ft. 8½-in.

Java—3-ft. 6-in.

Turkey in Asia—4-ft. 8½-in.

Ceylon—5-ft. 6-in. and 2-ft. 6-in.

Japan—3-ft. 6-in.

STANDARD RAILWAY FORMATIONS.—The following are a few of the dimensions adopted in high class British Railway construction.

Gauge of rails		4-ft. 8½-in.	5-ft. 3-in.	metre
Single line—	Minimum width of bank	17-ft.	18-ft.	14-ft.
	Usual width of bank	22-ft.	20-ft.	16-ft.
	Width, ordinary cutting, excluding side drains	16-ft.	18-ft.	14-ft.
Double line—	Minimum width of bank	28-ft.	30-ft.	26-ft.
	Usual width of bank	33-ft.	34-ft.	28-ft.
	Width, ordinary cutting, excluding side drains	27-ft.	30-ft.	26-ft.
Ballast—	Minimum width at top	11-ft.	10-ft. 6-in.	7-ft. 6-in.
	Depth below sleeper	12-in.	8-in.	6-in.
Sleepers—	Minimum length of cross sleeper	9-ft.	9-ft. 6-in.	6-ft.
	Minimum number per mile	1760	1936	1760
	Usual number per mile	2112	2112	2112

NOTES ON TIMBER.

There are so many text books which deal specially with all kinds of timber in general use that it would be superfluous (even if limits of space permitted) to attempt to deal with the subject exhaustively, but the following brief notes relating to Australian timbers may be useful.

SIZE AND GROWTH OF JARRAH AND KARRI TREES.—Owing to various circumstances, principally perhaps on account of facilities for shipment, these two are by far the best known of the 600 species of timber trees which flourish in Australia and the supply is practically inexhaustable.

Jarrah.—These trees can be obtained in large quantities up to 22 feet circumference near to the ground, the first branch often being at a height of about 80 feet.

They attain a circumference of about two feet in two years and are fit for the sawmill in 40 to 50 years.

Karri grows to very large size, but trees 4 feet diameter at 4 feet from the ground and 120 to 150 feet to the first branch are commonly met with.

The trees attain a base diameter of 2 feet and a height of about 150 feet in 30 to 40 years. *J. A. McDonald.*

COMBUSTIBILITY OF JARRAH AND KARRI TIMBER.—In tests recently carried out by the construction of a warehouse floor these timbers were used for supports, beams and floor boards carrying a load of 200-lbs. per square foot.

This structure was subjected to a fire test for two hours, the temperature being gradually increased to 2000° Fah., with the result that although the fire broke through the floor boards towards the end of the operations, the beams withstood the strains and continued to support the load.—(*Engineer*).

STRENGTH OF JARRAH AND KARRI TIMBER.—The following results deduced from careful tests of large beams by Mr. J. A. McDonald, M. Inst. C.E., are interesting because they are greatly at variance with those obtained by Mr. Fernow, with American timber, mentioned further on, and even with Professor Warren's deductions from tests made on small beams of Australian timber.

The tests were made on beams, 12 inches by 12 inches, resting on supports 25 feet apart, with the result given below, M.R. representing the modulus of rupture, and M.E. the modulus of transverse elasticity, both in pounds per square inch of area :

Jarrah	...	M.R. 8,828 lbs.	M.E. 2,426,659 lbs.
Karri	...	M.R. 7,895 lbs.	M.E. 3,168,355 lbs.

Margins of safety.—In his opinion (unless alternations of stress are very rapid) a factor of safety of 4 is ample, instead of the factor of 10 usually provided, and no doubt fixed to cover contingencies of which, at that time, little was known.

Small beams.—From experiments made by Professor Warren, M. Inst. C.E., he deduced a modulus of rupture of 12,000 lbs. for Jarrah, and 10,150 lbs. for Karri, or about 40 per cent. higher than those obtained by Mr. McDonald with large beams.

STRENGTH OF TIMBER BEAMS.—Extensive tests, made by Mr. Fernow (U.S. Department of Forestry) to ascertain the cross breaking strain of timber, show that large beams are as strong, or stronger, than is indicated by small specimens cut from them.

This is attributed to the fact that straight grained timber being the exception rather than the rule, a relatively larger proportion of fibres are oblique to the axis in the small specimens than in large beams, and hence do not represent the actual strength of the timber. (See also notes on Jarrah timber).

TEST FOR TIMBER.—The superior quality of timber felled in winter (October to April) is attributable to the presence of particles of starch which are not found in summer hewn timber.

These particles can be detected by coating freshly sawn wood with Iodine and observing the colour of the fibres. If the timber is winter felled the fibres will be violet ; if summer hewn they will be yellow.

SPARE PARTS FOR ENGINES AND MACHINERY.—The following details for parts of engines and machinery which have failed from all causes—including carelessness—are abstracted from an interesting report recently presented by Mr. Longridge M.Inst. C.E. to the Engine, Boiler, and Employers' Liability Insurance Company (Limited).

This carefully compiled list of parts which have failed is valuable as indicating the directions in which efforts for further improvements in construction should be made, as well as the provision of spare parts to replace those most likely to fail.

PARTS MOST LIKELY TO FAIL.

	During 1898.	During previous 16 years.	Total.
Valves and valve gear	33	423	456
Air pump buckets and valves	21	188	209
Spur gearing	19	408	427
Cylinders, valve chests, and covers	12	83	95
Air pump motions	11	251	262
Columns, entablatures, bedplates and pedestals	10	174	184
Parallel motions, links and guides	8	122	130
Main shafts	8	117	125
Connecting rods	8	34	42
Piston rod crossheads	7	51	58
Pistons	6	58	64
Air pumps and condensers	6	42	48
Flywheels	5	45	50
Governor gear	4	59	63
Crank pins	3	30	33
Bolts	2	145	147
Piston rods	1	47	48
Gudgeons in beams	1	25	26
Beams and side levers	1	21	22
Cranks	0	33	33
Total wrecks, cause unknown	0	6	6
Second motion shafts	0	3	3
Main driving ropes and belts	0	3	3
	166	2368	2534

Defects in gearing.—Mr. Longridge also points out that troubles arising from defective gearing have largely decreased since rope driving and the substitution of steel for cast iron geared wheels has become more general. The use of machine cut teeth also tends in the same direction.

LIFE OF INDIA-RUBBER.—Rubber submerged in water, or stored in a dark room of fairly even temperature, retains its properties for many years, but it cannot be expected to do so when continuously exposed to the sun's rays, or when used—as in tubes—for carrying steam at a pressure of 50-lbs (or more) per square inch.

RUBBER STEAM TUBE.—A detail often overlooked is the position of the shut-off valve. If this is fixed near to the machine to be operated, when the valve is closed the whole of the tube is exposed to the heat and full pressure of steam and variations thereof, all which is avoided, and the life of the tube indefinitely increased, if the valve is at the end nearest the boiler.

The manufacturer is blamed for the failure of materials used under the above-named and other improper conditions, although the trouble is due to needlessly continuous exposure to heat which causes the rubber to lose its pliability and, in a comparatively short time, becomes brittle and useless; and the lower the quality of rubber the sooner this happens.

The prices of rubber tube will be found in Section III.

QUALITY OF RUBBER.—Low price is often regarded as more important than high quality, but experience shows that, for nearly all mechanical purposes, good rubber is the most economical; also, that if properly used and not in contact with oil or grease, it will be reliable for years. The low qualities, however, deteriorate rapidly under continuous use.

STATISTICS OF CHAIN ACCIDENTS.—A report of the Inspector of Factories shows that 115 fatal accidents and 459 non-fatal accidents occurred in 1899 at Docks, Quays and Wharves, and the opinion is expressed that further and more systematic precautions should be taken in maintaining chains, ropes and machinery in efficient condition.

Those only who are familiar with the mode in which work is carried on in water-side premises can appreciate the difficulties in their management, and the reference at page 230 to the measures necessary for proper maintenance (written long before the above-named report was published) may be worthy of attention.

MACHINE ECONOMIES.

MACHINE AND HAND LABOUR.—The following data relating to the saving affected by the use of machinery in the operations referred to serves to indicate the vast progress made since 1850. The information is (for the most part) abstracted from a report issued by authorisation of Congress (U.S.A.)

Saving in labour.—As little or no skilled labour is required to work most of the machines mentioned, to arrive at the total saving effected by the use of machinery, the saving in amount paid in wages must be added to that due to accelerated speed of working.

Corn.—To produce and harvest an acre of corn in 1850 required 182⅗ hours of labour. The same work is now done by machinery in 27 hours.

In 1830, harvesting an acre of wheat required 64 hours labour; it can now be done in three hours.

Hay.—In 1850, 21 hours were required to harvest an acre of hay. The same work is now done in four hours.

Brick-making.—About 1000 bricks are produced by hand-work in 20 hours of labour. The same quantity is produced by machine in 7½ hours and a similar saving is effected in making drain pipes, tiles, etc.

Carpet weaving.—In 1850 4·04 hours hand labour were required to produce one square yard of Brussels carpet. It is now turned out by power looms at the rate of one square yard in half-an-hour.

Cotton manufacture.—Before the introduction of machinery for the preparation of the cotton and weaving, 500 yards of cotton sheeting required 5605 hours labour. The same quantity is now produced by machinery with 52⅗ hours labour.

Carding cotton by hand, for 500 yards of sheeting required 1980½ hours of labour. It is now done by the carding machine in 28·7 minutes.

Cotton spinning and reeling.—The ratio in favour of the machine is about 200 to 1 in spinning; in reeling it is about 350 to 1.

Cotton weaving.—The advantage of machine over hand labour varies from about 11 to 30 to 1.

Bolt and nut making.—The gain in speed of production is about 8·6 to 1 in favour of machine work, the quality being improved.

Wood sawing.—A modern saw-mill turns out boards in about 1-60th of the time required for conversion by hand sawing, and with much less waste.

Rock drills, driven by steam or compressed air, will put down 30 holes 2½ inches diameter and 18 inches deep in granite in less than 15 hours, whilst 89 hours would be required to perform the same work by hand.

Lifting machinery.—An ordinarily efficient steam, electric, or hydraulic crane, occupying very little space, will perform identical work at 1-10th of the cost and in 1-10th of the time that was required to perform it in 1850.

The same (or even higher) ratios may be applied for mining and many other operations, but accurate data relating to the extent of reduction in cost and the increase in speed of lifting and transferring large masses of materials, can only apply to individual operations.

MEMORANDA RELATING TO WATER.

One cubic foot of water = 6¼ gallons.

An imperial gallon of water at 62 degs. Fahr. weighs 10lb. avoirdupois.

Gallons multiplied by ·16045 = cubic feet.

Cubic feet multiplied by 6·232 = number of gallons.

Gallons multiplied by 277·274 = cubic inches.

Cubic inches multiplied by ·00360 = number of gallons.

Cubic feet of water × 62·35 = number of pounds weight.

Pounds of water multiplied by ·0160 = cubic feet.

Gallons of water × ·0044 = number of tons.

Tons of water × 223·897 = gallons of water.

Cubic feet of water × 35·92 = number of tons.

Tons of water × ·02783 = cubic feet of water.

A cubic foot of water weighs about 62·5 pounds.

A cubic foot of water contains about 6·25 gallons.

A ton of water contains about 35·9 cubic feet.

A column of water produces a pressure in pounds per square inch equivalent (approx.) to half the height in feet.

Water is at its greatest density when at a temperature of 39·1 degs. Fahr. Water expands as its temperature is increased above 39·1 degs. The rate of expansion above 212 degs. Fahr. is unknown. Each degree of difference in temperature of feed water to a boiler makes a difference of ·00104 in the amount of evaporation.

A column of water 1 foot high = pressure of ·434 lb. per square inch.

A pressure of 1 lb. per square inch = column of water 2·31 feet high.

One gallon = 4·543 litres.

A miner's inch = approximately 100 cubic feet of water per hour, and the cost is usually about 10d. The term, however, which is used in California, is very elastic.

One litre of water = ·22 gallon.

One cubic metre of water = 220 gallons.

One cubic metre of water = 1,000 kilos.

One cubic metre of water = 1,000 litres.

One cubic metre of water = 1 ton (approx.)

One kilo. of water = 2·204 lb.

One inch of rainfall = one gallon of water spread over a surface of nearly two square feet.

One inch of rainfall = about 100 tons per acre.

Inches of rainfall × 2·323 = cubic feet per square mile.

POWER REQUIRED TO RAISE WATER FROM DEEP WELLS.

Gallons of water raised per hour	200	350	500	650	800	1000
Height of lift for one man working on crank in feet ...	90	52	36	28	22	18
Height of lift for one donkey working on gin in feet ...	180	102	72	56	45	36
Height of lift for one horse working on gin in feet ...	630	357	252	196	154	126
Height of lift for one horse-power steam engine in feet	990	561	396	308	242	198

The foregoing table is based on the assumption that a good class of treble or double-barrel lift pump is used, with valves in the buckets, and an additional retaining valve for lifts above 100ft.

RELATIVE VALUES OF STEAM, ANIMAL, AND MANUAL POWER IN WATER LIFTED.—The subjoined figures will enable anyone to estimate the power required for raising a given quantity of water, and—by reference to the descriptions of various types of pumps given in Section III.—to determine which of the appliances are best adapted for the work to be performed.

Steam (or other motor) horse-power, as is well known, is equal to raising 33,000 lbs. to a height of one foot in one minute. As one Imperial gallon of water weighs 10 lbs. it follows that one horse-power will raise 3,300 gallons to a height of one foot, or 330 gallons to a height of 10 feet, and so on. For losses in friction see below.

The power exerted by animals working eight hours a day, is equal (approximately) to raising the under-named quantities per minute, to a height of one foot.

One horse about	... ...	21,000 foot pounds
One bullock about	... ...	12,000 ,,
One mule or pony	... ...8,000 to	10,000 ,,
One donkey	... ...3,500 to	4,000 ,,

Manual power naturally varies very greatly, but may be expected to range from 2,000 to 3,000 foot pounds.

The speed of working is usually from 20 to 30 revolutions of the handle per minute, the power exerted on the handle being 15 to 25 lbs.

The losses in friction in gear, pipes, etc., also vary widely, and 25 per cent. (at least) should be allowed for losses arising from these causes.

COMPARATIVE COST OF PUMPING WATER.—The cost of pumping 1000 gallons of water to a height of 100 feet by the methods commonly employed for small supplies, has been ascertained by Mr. J. C. Fell to be as follows:—

Hand labour at wages 18/- per week	26·5 pence
Horse power, man at 18/- per week	4·20 ,,
Gas engine driving with gas at 4/- per thousand cubic feet	1·44 ,,
Steam pump and boiler with coal at 20/- per ton... ...	0·75 ,,
Oil engine worked by oil at 7d. per gallon	0·70 ,,
Electric motor with current from a lighting dynamo .	0·45 ,,

The hydraulic ram is, however, the cheapest and most durable water raiser and the cheapest motive powers are waterwheel and windmill, if they can be provided at moderate cost for installation.

RAINFALL AND TEMPERATURE IN GREAT BRITAIN.—The figures in the following table present fair averages of atmospheric conditions in this country, and may be useful for comparison with current weather :

Months.	Temperature.		Rainfall.			Pressure.		Wind.	Sunshine.
	Mean	Diff. from normal.	Mean days.	Mean amount.	Diff. from normal.	Mean.	Diff. from normal.	Resultant.	Percentage.
	°	°		inches.	inches.	inches.	inches.		hours.
November	51	6 above	17	3·96	0·16 less	29·98	0·11 above	SW	22
December	43	1 ,,	23	6·22	2·03 more	29·81	0·04 below	S	16
January ...	44	3 ,,	28	5·26	1·32 ,,	29·83	nil	W*b*S	20
February..	39	2 below	20	4·18	1·09 ,,	29·54	0·33 below	NW	27
March	41	2 ,,	17	1·50	1·16 less	30·05	0·21 above	N*b*E	27
April.......	47	nil	18	2·12	0·23 ,,	29·90	nil	W	40
May........	50	1 below	15	2·42	0·32 more	29·92	0·04 below	SW*b*S	37
June........	55	1 ,,	18	2·92	0·70 ,,	29·89	0·05 ,,	SW*b*W	34
July	60	1 above	17	1·69	1·30 less	29·95	0·03 above	W	42
August.....	58	1 below	16	3·24	0·04 ,,	29·96	0·06 ,,	WNW	38
September	58	2 above	15	2·22	1·20 ,,	30·05	0·08 ,,	W*b*S	44
October ...	51	1 ,,	22	4·20	0·01 more	29·87	0·05 ,,	W	30

Whitaker.

INFILTRATION.—The subjoined table gives the results of Mr. Dickenson's observations, extending over eight years, where the soil was sandy gravelly loam overlaying chalk.

The rainfall during the above-named period was below the average, so that the figures do not quite coincide with those in the preceding table:

Months.	Mean fall. inches.	Mean infiltration. inches.	Percentage.
November, December and January ...	7·325	6·370	86.9
February, March and April	5·044	2·930	58·0
May, June and July	6·356	0·189	2·9
August, September and October ...	7·889	1·805	22·8
Totals	26·614	11·294	42·4

EVAPORATION.—The mean daily evaporation in England is ·08-inch, or more than 50 per cent. of the rainfall, but the rate of the evaporation varies with the district, being considerably greater in undulating rocky districts than in level country.

STORAGE.—Above 60 per cent. of the total rainfall is estimated to be available for storage in England, but a loss of 10-per cent. should be allowed for overflow of storm water.

WEIGHT OF WATER.—Sea water contains, on an average, 3·44 of solid matter, but it varies considerably, the water of the Red Sea containing 4·3 per cent. and that of the Baltic 5 per cent.

The weight of a cubic foot of average sea water at the standard temperature is 64 lbs., and its specific gravity, compared with fresh water, is 1·026 lbs.

The following table gives the weight, volume, etc. of fresh water at the four principal temperatures.

Condition of Water.	Temperature.		Weight.			Volume of 1 lb. of water.	
	Fahrenheit.	Centigrade.	Cubic ft. lbs.	Cubic in. lbs.	Cubic in. ozs.	Cubic feet.	Cubic inches.
Freezing point under 1 atmosphere	32°	0°	62·418	·03612	·5779	·016021	27·684
Point of maximum density ...	39·1°	4°	62·425	·03612	·5780	·016019	27·680
Point of British standard of weight	62°	16·66°	62·355	·03608	·5773	·016037	27·712
Boiling point under 1 atmosphere	212°	100°	59·640	·03451	·5522	·016770	28·978

It may be here remarked that the standard used in France for comparing the specific gravity of solids is pure water at its maximum density, or 4° centigrade; this should not be overlooked when using French tables of specific gravities.

PIPES AND CONNECTIONS.—The pipes should be of ample diameter, in proportion with their length, to minimise the loss in friction, and for the same reason sharp bends or inequalities should—as far as possible—be avoided. If inequalities in levels are unavoidable, a valve or cock will be required at the highest point to allow imprisoned air to escape.

SUCTION PIPES.—It is well known—but by no means always remembered—that the so-called "Suction" is due merely to the pressure of the atmosphere which, at sea level, is 14·7 lbs. per square inch, or equivalent to a column about 30 feet high, so that the foot of the suction pipe must always be immersed, and (allowing for possible leakages) must in no case be more than 27 feet from lowest water level for large pumps and less than that for small pumps, the height being reduced in proportion, with increase in temperature of the water beyond about 55°. When boiling point (212°) is reached, the water must flow freely into the pump with a head of not less than two or three feet.

If the suction pipe cannot be carried vertically from the pump to the water, it should rise gradually and be provided with a foot valve. A strainer is obviously desirable, unless the water is exceptionally free from floating matter.

Where a "Sumph" cannot be provided of sufficient depth to allow stones, sand and debris to settle below the intake to the pumps, it should be protected by a box, which will maintain a fairly undisturbed surface around the suction pipe. For large pumps an arrangement similar to that indicated in Fig. 1626 (Section 1) may be adopted with advantage.

JOINTS OF PIPES AND CONNECTIONS.—These should be carefully made to guard against leakage of air and water. Much loss of time and labour may be avoided if pipes are thoroughly tested when laid, and before they are covered.

AIR VESSELS AND STAND PIPES are necessary adjuncts for equalising the flow of water. The stand pipe which is open to the atmosphere at the top, effectually limits the pressure in the rising main to that due to the height of the stand pipe.

VELOCITY OF WATER IN PIPES.—This question is largely affected by the conditions fulfilled by the pump. From 2 to 4 feet per second is a convenient velocity for comparatively small pumps which are in constant use, whilst for a centrifugal pump (especially if worked intermittently and discharging at or near the pump) a velocity of 10 to 12 feet per second, although not economical, is not at all exceptional. See table pages 285 and 286.

FRICTION IN PIPES increases directly in the ratio of length, and approximately, as the square of the velocity of the flow. See table page 107.

CAPACITIES OF PIPES.—These are given in detail in the table pages 286 to 288, but a useful note for approximate calculation is, that a pipe one yard long holds about as many lbs. of water as the sum of the square of the diameter of the pipe in inches.

HAND PUMPS.—The principal features in hand power pumps are that the bucket and valve shall be, as far as possible, indestructible, and shall free themselves easily from obstructions.

An experience of half a century indicates that the Appleby valve for small sizes (up to about 5 or 6 inches diameter), and the ordinary weighted leather flap for larger sizes, best fulfil the above-named conditions.

COST OF INSTALLATIONS FOR WATER POWER.—The works required to convey water to and from the Turbine has cost as much as £40 per horse power developed, but the average will be £10 to £15.

COST OF WORKING BY WATER SUPPLY.—With an efficient installation of 100 horse power, or more, working day and night, the cost is not more than £2 per horse power per annum.—*Addenbrook.*

WATER SUPPLY PER HEAD OF POPULATION.—This varies in Great Britain between 50 gallons per head of population per day in Glasgow, and 15 gallons in Durham.

The late Mr. Hawksley stated that 15 gallons per head per day was sufficient supply for residential districts, and experience shows this to be ample, provided that pipes and fittings are well attended to, and leakages stopped as soon as they occur.

If, however, water is required for manufacturing purposes, the above-named supply will, necessarily, be inadequate.

FLOW OF SEWAGE.—One of the difficulties incidental to sewage disposal is the constant variation in the quantity and quality passing through the sewers during the day.

The maximum flow is (in England) usually about 10 to 11 a.m. and 3 to 4 p.m. when the quantity is eight to ten times the minimum at about midnight, hence the difficulty in determining the dimensions and gradients of sewers.

The separate system mitigates the above-named difficulties and deserves careful consideration.

WATER SUPPLY.—The quantity of water consumed per day naturally varies with the trades carried on in the district, but examination of the consumption in many localities indicates that 20 gallons per head, per day, is ample for domestic purposes.

If water for trade purposes is included, 40 gallons per head, per day or more may be consumed; it is usually supplied by meter.

TOWN WATER SUPPLY.—One cubic foot per second will supply 25,000 inhabitants with 20 gallons of water per day, after allowing $7\frac{1}{2}$ per cent for waste.

FILTER BEDS.—The rule adopted by the late Sir Robert Rawlinson provides that sand filter beds should not have to filter more than 50 gallons of water per 24 hours for each superficial foot of sand surface.

COVERED STORAGE RESERVOIRS.—Protecting the surface of the water from the heat of the sun minimises evaporation, and—by excluding light—prevents the growth of algœ, which spoils the taste and appearance of the water and, at times, renders it unusable.

Brick, tile, and concrete have been used for covering reservoirs, but wood planking about 1-in. thick provides the necessary protection and has proved quite satisfactory.

The planking is secured to a framework of timber joists supported on water pipes of 2-in. diameter, coated with asphalt, and spaced about 18 feet apart longitudinally and 16 feet transversely. The lower ends of the pipes are embedded in the concrete with which the reservoir is lined.

The cost of covering a reservoir of 21,000,000 gallons capacity and 166,000 square feet area of roof is about 2·18d. per square foot, including all charges for materials, labour, and engineering.

The timber used was Oregon pine, and cost £3 15 0 per 1000 feet, B.M.

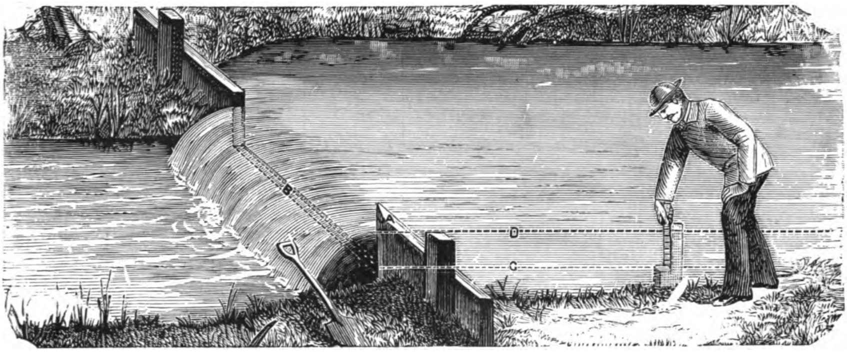


Fig. 5177.

GAUGING WATER SUPPLY.—The quantity of water passing in a given time can be ascertained, approximately, by the well-known rule relating to discharge through orifices, but less accurately than by the notched weir, or tumbling bay, represented by Fig. 5177.

THE NOTCHED WEIR or TUMBLING BAY.—This must be wide and deep enough to pass all the water to be measured. The bottom board **B** is level and is fixed at a height which will give a fall of not less than six inches on the down stream side; the top edge of this board, as well as the vertical edges of the notch, are bevelled from the upstream side to present a sharp edge on that side, as shown at **A**, and the structure is made water tight with puddle. A stake is fixed about 6 feet above the weir, level with the top of the longitudinal board **B**, and the dotted lines **C** and **D** represent respectively, the level of the water when passing over the weir and that of the surface, etc. The measurement between **C** and **D** represents the number of inches flowing over the weir; this, multiplied by the number of inches between the notches, and by the proper figures in the following table, gives the number of cubic feet of water delivered per minute over a weir of any length.

INFORMATION RELATING TO PUMPING PLANT.—This should consist of:

1. A reference to illustrations in Section III., or description of the installation required, or—failing that—details of the conditions under which it is to be used; also whether low cost or highest efficiency is the important consideration.
2. The maximum duty to be rendered in a given time, and the nature of fluid to be raised.
3. Drawings or sketches with figured dimensions showing the position of the pumps relatively with the suction water level, and the height from it to the point of discharge.
4. If steam is to be supplied from existing boilers, the minimum pressure available should be stated, and the distance between boilers and pumps.
5. If boilers are required, the type will be conveniently defined by reference to Section I. of this Handbook, or failing that, information should be given with regard to fuel, difficulties relating to transport (if any), boiler setting, &c.
6. If the pumps are driven from an existing motor or shaft, the speed of the driven shaft should be stated, and the restrictions (if any) to the diameter of the pulley.

TABLE FOR ESTIMATING THE CUBIC FEET PER MINUTE PER INCH OF LENGTH OF WEIR.

che Depth on Weir.	FRACTIONS OF AN INCH.							
	0	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
0	0	.01	.05	.09	.14	.20	.26	.33
1	.40	.47	.55	.65	.74	.83	.93	1.03
2	1.14	1.24	1.36	1.47	1.59	1.71	1.83	1.96
3	2.09	2.23	2.36	2.50	2.63	2.78	2.92	3.07
4	3.22	3.37	3.52	3.68	3.83	3.99	4.16	4 32
5	4.50	4.67	4.84	5.01	5.18	5.36	5.54	5.72
6	5.90	6.09	6.18	6.47	6.65	6.85	7.05	7.25
7	7.44	7.64	7.84	8.05	8.25	8.45	8.66	8.86
8	9.10	9.31	9.52	9.74	9.96	10.18	10.40	10.62
9	10.86	11.08	11.32	11.54	11.77	12.00	12.23	12.47
10	12.71	13.05	13.19	13.43	13.67	13.93	14.16	14.42
11	14.67	14.92	15.18	15.43	15.67	15.96	16.20	16.46
12	16.73	16.99	17.26	17.52	17.78	18.05	18.32	18.58
13	18.87	19.14	19.42	19.69	19.97	20.24	20.52	20.80
14	21.09	21.37	21.65	21.94	22.22	22.51	22.79	23.08
15	23.38	23.67	23.97	24.26	24.56	24.86	25.16	25.46
16	25.76	26.06	26.36	26.66	26.97	27.27	27.58	27.89
17	28.20	28.51	28.82	29.14	29.45	29.76	30.08	30.39
18	30.70	31.02	31.34	31.66	31.98	32.31	32.63	32.96
19	33.29	33.61	33.94	34.27	34 60	34.94	35.27	35.60
20	35.94	36.27	36.60	36.94	37.28	37.62	37.96	38.31
21	38.65	39.00	39.34	39.69	40.04	40.39	40.73	41.09
22	41.43	41.78	42.13	42.49	42.84	43.20	43.56	43.92
23	44.28	44.64	45.00	42.38	45.71	46.08	46.43	46.81
24	47.18	47.55	47.91	48.28	48.65	49.02	49.39	49.76

The velocity of current is easily ascertained by taking the time occupied by a corked bottle, or other object, in floating a distance of (say) 20 or 30 yards.

NOTES ON WATER POWER.

EFFICIENCY OF TURBINES.—The conditions under which Turbines of different types give the best results are referred to at pages 84 to 88 of Section 1 of this series, so that it will only be necessary to mention here, that the efficiency usually ranges from 60 to 80 per cent. of the water power supplied to them.

If the most suitable construction is adopted, an efficiency of about 75 per cent. may therefore be expected.

Information required.—In the absence of specific instructions details of construction, information should be given with reference to.

The minimum horse-power required.

The number of cubic feet of water permanently available and the free height of fall.

The manner in which the tail race water will be carried away.

EFFICIENCY OF WATER WHEELS.—According to the investigations carried out by M. Poncelet and M. Morin, this ranges from 27 to 80 per cent. the results obtained from the different forms being :

Overshot wheels 60 to 80 per cent. **Breast wheels** 45 to 50 per cent. and **undershot wheels** 27 to 30 per cent.

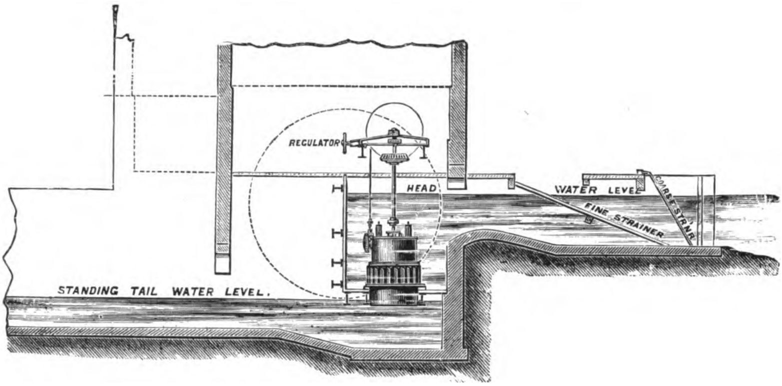


Fig. 5178.

TURBINE AND STRAINER.—Fig. 5178 represents a type of low fall turbine which admits of the immersion of the discharge outlet, in the tail race, with corresponding gain in power developed, and suitable for many conditions.

The strainer arrangements have been completely successful in preventing refuse matter from reaching the turbine, and serves to indicate a construction which can be carried out by any carpenter.

Power developed.—The following table, calculated on an efficiency of 75 per cent., gives the quantity of water in cubic feet per minute required for each horse power, when acting under different falls; for instance, if any available quantity of water be divided by the cubic feet required per horse power with a given fall, (as ascertained from the table), the quotient will be the horse power at command. Or conversely: with a given head, any proposed horse power multiplied ay the number of cubic feet required per horse power (taken from the table), will give the number of cubic feet per minute required to produce the proposed horse power, with that head.

NUMBER OF CUBIC FEET REQUIRED PER H.P. PER MINUTE.

Head in Feet.	0	1	2	3	4	5	6	7	8	9
0	...	710	355	237	178	142	118	101	88.8	78.9
10	71	64.5	59.3	54.6	50.8	47.3	44.5	41.7	39.5	37.4
20	35.5	33.8	32.3	30.9	29.6	28.4	27.3	26.3	25.3	24.5
30	23.7	22.9	22.2	21.5	20.9	20.3	19.7	19.2	18.7	18.2
40	17.8	17.3	16.9	16.5	16.1	15.8	15.4	15.1	14.8	14.5
50	14.2	13.9	13.7	13.4	13.1	12.9	12.7	12.5	12.2	12.0
60	11.8	11.6	11.4	11.3	11.1	10.9	10.8	10.6	10.4	10.3
70	10.1	10.0	9.86	9.72	9.59	9.47	9.34	9.22	9.11	8.99
80	8.88	8.77	8.66	8.55	8.45	8.35	8.25	8.15	8.06	7.97
90	7.89	7.80	7.72	7.63	7.55	7.47	7.39	7.32	7.24	7.17
Head in Feet.	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
100	7.1	6.45	5.73	5.46	5.08	4.73	4.43	4.17	3.95	3.74
200	3.55	3.38	3.23	3.09	2.96	2.84	2.73	2.63	2.53	2.45
300	2.37	2.29	2.22	2.15	2.09	2.03	1.97	1.92	1.87	1.82
400	1.78	1.73	1.69	1.65	1.61	1.58	1.54	1.51	1.48	1.45
500	1.42	1.39	1.37	1.34	1.31	1.29	1.27	1.25	1.22	1.20
600	1.18	1.16	1.14	1.13	1.11	1.09	1.08	1.06	1.04	1.03
700	1.01	1.00	.986	.912	.959	.947	.934	.922	.911	.899
800	.888	.877	.866	.855	.845	.835	.825	.815	.806	.797
900	.788	.780	.772	.763	.755	.747	.739	.732	.724	.717

CAPACITIES OF RECIPROCATING PUMPS.—The following table gives the approximate **theoretical** duties of single acting pumps (one barrel) up to 24 inches diameter, when working at given speeds and lengths of stroke, and furnishes the data for readily ascertaining the capacities at other speeds and lengths of stroke.

For double acting and double barrel pumps multiply the figures by two.

For treble barrel pumps multiply the figures by three.

For losses due to friction, wear of packings, etc. a deduction should be made of not less than 10 per cent.

CAPACITIES OF PUMPS IN GALLONS PER HOUR.

Length of Stroke.	3 inches.				6 inches.			
Strokes per minute.	10	20	30	40	10	20	30	40
1-in. diam., gallons per hour	5	10	15	20	10	20	30	40
1¼-in. ,, ,, ,,	8	16	24	32	16	32	48	64
1½-in. ,, ,, ,,	11	22	34	44	22	44	66	88
2-in. ,, ,, ,,	20	40	60	80	40	80	120	160
2½-in. ,, ,, ,,	32	64	96	128	64	128	192	256
3-in. ,, ,, ,,	46	92	138	184	92	184	276	368
3½-in. ,, ,, ,,	62	124	186	248	124	248	372	496
4-in. ,, ,, ,,	81	162	243	324	162	324	486	648
4½-in. ,, ,, ,,	103	206	309	412	206	412	618	824
5-in. ,, ,, ,,	126	252	378	504	252	504	756	1008
6-in. ,, ,, ,,	182	364	546	728	364	728	1092	1456
7-in. ,, ,, ,,	249	498	747	996	498	996	1494	1992
8-in. ,, ,, ,,	325	650	975	1300	650	1300	1950	2600
9-in. ,, ,, ,,	412	824	1236	1648	824	1648	2472	3296
10-in. ,, ,, ,,	509	1018	1527	2036	1018	2036	3054	4072
12-in. ,, ,, ,,	732	1464	2196	2928	1464	2928	4392	5856
15-in. ,, ,, ,,	1145	2290	3435	4580	2290	4580	6870	9160
18-in. ,, ,, ,,	1645	3296	4944	6592	3296	6592	9888	13184
21-in. ,, ,, ,,	2250	4500	6750	9000	4500	9000	13500	18000
24-in. ,, ,, ,,	2930	5860	8790	11720	5860	11720	17580	23440

CAPACITIES OF PUMPS IN GALLONS PER HOUR (*Continued*).

Length of Stroke.	9 inches.				12 inches.			
Strokes per minute.	10	20	30	40	10	20	30	40
1-in. diam., gallons per hour	15	30	45	60	20	40	60	80
1¼-in. ,, ,, ,,	24	48	72	96	32	64	96	128
1½-in. ,, ,, ,,	33	66	99	132	44	88	132	176
2-in. ,, ,, ,,	60	120	180	240	80	160	240	320
2½-in. ,, ,, ,,	96	192	288	384	128	256	384	512
3-in. ,, ,, ,,	138	276	414	552	184	368	552	736
3½-in. ,, ,, ,,	186	372	558	744	248	496	744	992
4-in. ,, ,, ,,	243	486	729	972	324	648	972	1296
4½-in. ,, ,, ,,	309	618	927	1236	412	824	1236	1648
5-in. ,, ,, ,,	378	756	1134	1512	504	1008	1512	2016
6-in. ,, ,, ,,	546	1092	1638	2184	728	1456	2184	2912
7-in. ,, ,, ,,	747	1494	2241	2988	996	1992	2988	3984
8-in. ,, ,, ,,	975	1950	2925	3900	1300	2600	3900	5200
9-in. ,, ,, ,,	1236	2472	3708	4944	1648	3296	4944	6592
10-in. ,, ,, ,,	1527	3054	4581	6108	2036	4072	6108	8144
12-in. ,, ,, ,,	2196	4392	6588	8784	2928	5856	8784	11712
15-in. ,, ,, ,,	3435	6870	10305	13740	4580	9160	13740	18320
18-in. ,, ,, ,,	4944	9888	14832	19776	6592	13184	19776	26368
21-in. ,, ,, ,,	6750	13500	20250	27000	9000	18000	27000	36000
24-in. ,, ,, ,,	8790	17580	26370	35160	11720	23440	35160	46880

LOSS OF HEAD IN FEET DUE TO FRICTION OF WATER IN PIPES PER YARD RUN.

DIAM. OF PIPE IN INCHES. / GALLS. PER MINUTE.	1	1½	2	2½	3	3½	4	5	6	7	8	9	10	12	14	16	18
5	·102	·013	·003	·001	...	...	...	...	...	...	...	...	...	...	...	...	...
10	·411	·054	·012	·004	·002	...	...	...	...	...	...	...	...	...	...	...	...
15	·926	·122	·029	·009	·004	·002	...	...	...	...	...	...	...	...	...	...	...
20	1·64	·216	·051	·016	·006	·003	·002	...	...	...	...	...	...	...	...	...	...
30	3.70	·487	·115	·037	·015	·007	·003	·001	...	...	...	...	...	...	...	...	...
40	...	·867	·205	·067	·027	·012	·006	·002	...	...	...	...	...	...	...	...	...
50	...	1·35	·321	·105	·042	·019	·010	·003	·001	...	...	...	...	...	...	...	...
60	...	1·95	·463	·151	·060	·028	·014	·004	·002	...	...	...	...	...	...	...	...
70	...	2·65	·630	·206	·083	·038	·019	·006	·002	·001	...	...	...	...	...	...	...
80	...	3·46	·823	·269	·108	·050	·025	·008	·003	·002	...	...	...	...	...	...	...
90	...	...	1.04	·341	·137	·063	·032	·010	·004	·002	·001	...	...	...	...	...	...
100	...	...	1·28	·421	·169	·078	·040	·013	·005	·002	·001	...	...	...	...	...	...
120	...	...	1·85	·606	·243	·112	·057	·018	·007	·003	·002	·001	...	...	...	...	...
140	...	...	2·52	·825	·332	·153	·078	·025	·010	·004	·002	·001	...	...	...	...	...
160	...	...	3·29	1·07	·433	·200	·102	·033	.013	·006	·003	·002	·001	...	...	...	...
180	...	...	...	1·36	·549	·253	·131	·042	·017	·008	·004	·002	·001	...	...	...	...
200	...	...	...	1·68	·677	·313	·160	·052	·021	·009	·005	·002	·002	...	...	...	...
250	...	...	...	2·63	1·05	·489	·251	·082	·033	·015	·007	·004	·003	·001	...	...	...
300	...	...	...	3·79	1·52	·705	·361	·118	·047	·022	·011	·006	·004	·001	...	...	...
350	...	...	...	...	2·07	·960	·492	·161	·065	·030	·015	·008	·005	·002	...	...	...
400	...	...	...	...	2·71	1·25	·643	·210	·084	·039	·020	·011	·006	·002	·001	...	...
450	...	...	...	...	3·43	1.58	·813	·266	·107	·049	·025	·014	·008	·003	·002	...	...
500	...	...	...	...	...	1.95	1·00	·329	·132	·061	·031	·017	·010	·004	·002	·001	...
600	...	...	...	...	...	2·82	1·44	·474	·190	·088	·045	·025	·014	·005	·002	·001	...
700	...	...	...	...	...	3·83	1·96	·645	·259	·120	·061	·034	·020	·008	·003	·002	·001
800	...	...	...	...	...	...	2·57	·842	·338	·156	·080	·044	·026	·010	·004	·002	·001
900	...	...	...	...	...	...	3·25	1·06	·428	·198	·101	·056	·033	·013	·006	·003	·002
1000	...	...	...	...	...	...	...	1·31	·529	·244	·125	·069	·041	·016	·007	·004	·002
1250	...	...	...	...	...	...	...	2·06	·827	·382	·196	·109	·064	·026	·012	·006	·003
1500	...	...	...	...	...	...	...	2·96	1·19	·551	·282	·156	·092	·037	·017	·009	·005
1750	...	...	...	...	...	...	...	...	1·62	·750	·384	·213	·126	·050	·023	·012	·006
2000	...	...	...	...	...	...	...	...	2·11	·97	·50	·27	·164	·066	·030	·015	·008
2500	...	...	...	...	...	...	...	...	3·30	1·53	·785	·435	·257	·103	·047	·024	·013
3000	...	...	...	...	...	...	...	...	...	2·20	1·13	·62	·370	·148	·068	·035	·019
3500	...	...	...	...	...	...	...	...	...	3·00	1·53	·853	·504	·202	·093	·048	·026
4000	...	...	...	...	...	...	...	...	...	...	2·00	1·11	·658	·264	·122	·062	·034
5000	...	...	...	...	...	...	...	...	...	...	3·14	1·74	1·02	·413	·191	·098	·054
6000	...	...	...	...	...	...	...	...	...	...	...	2·50	1·48	·595	·275	·141	·078
7000	...	...	...	...	...	...	...	...	...	...	...	3·41	2·01	·810	·374	·192	·107
8000	...	...	...	...	...	...	...	...	...	...	...	...	2·63	1·05	·489	·251	·139
9000	...	...	...	...	...	...	...	...	...	...	...	...	3·33	1·33	·619	·317	·176
10000	...	...	...	...	...	...	...	...	...	...	...	...	...	1·65	·765	·392	·217
12500	...	...	...	...	...	...	...	...	...	...	...	...	...	2·58	1·19	·613	·339
15000	...	...	...	...	...	...	...	...	...	...	...	...	...	3·72	1·72	·883	·419
20000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·06	1·56	·871
25000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2·45	1·36
30000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·53	1.96

Tangye.

HEAD OF WATER IN FEET, EQUIVALENT PRESSURE PER SQUARE INCH, AND VELOCITY OF EFFLUX IN FEET PER SECOND.

HEAD FEET.	PRESSURE LBS. PER SQUARE INCH.	VELOCITY FEET PER SECOND.	HEAD FEET.	PRESSURE LBS. PER SQUARE INCH.	VELOCITY FEET PER SECOND.
0·1	0·043	2·54	70	30·1	67·1
0·2	0·086	3·59	75	32·25	69·5
0·3	0·129	4·39	80	34·4	71·8
0·4	0·172	5·07	85	36·55	74
0·5	0·215	5·67	90	38·7	76·1
0·6	0·258	6·22	95	40·85	78·2
0·7	0·301	6·71	100	43	80·3
0·8	0·344	7·18	110	47·3	84
0·9	0·387	7·61	120	51·6	87·68
1	0·43	8·03	125	53·75	89·7
2	0·86	11·4	130	55·9	91·5
3	1·29	13·9	140	60·2	94·7
4	1·72	16·06	150	64·5	98·3
5	2·15	17·9	160	68·8	101·2
6	2·58	19	170	73·1	104·5
7	3·01	21·2	180	77·4	107·2
8	3·44	22·7	190	81·7	110·4
9	3·87	24·1	200	86	113·5
10	4·3	25·4	225	96·75	120
11	4·73	26·6	250	107·5	126
12	5·16	27·8	275	117·25	133
13	5·59	28·9	300	129	139
14	6·02	30	325	143	144
15	6·45	31·1	350	150·5	150
16	6·88	32·1	375	161·25	155
17	7·31	33·1	400	172	160
18	7·74	34	425	182·75	165
19	8·17	35	450	193·5	170
20	8·60	35·9	475	204·25	174
25	10·75	40·1	500	215	179
30	12·9	43	525	225·75	184
35	15·05	47·4	550	236·5	188
40	17·2	50·7	575	247·25	192
45	19·35	53·8	600	258	197
50	21·5	56·7	625	268·75	200
55	23·6	59·5	650	279·5	204
60	25·8	62·1	675	290·25	208
65	27·9	64·75	700	301	212

For pressures due to other heads, alter the decimal point as necessary.

Example.—The pressure per square inch due to 80 feet head is 34·4 lbs. per square inch, therefore the pressure at 800 feet head is 344 lbs. per square inch, and so on.

VELOCITY OF WATER IN FEET PER MINUTE THROUGH PIPES OF VARIOUS SIZES FOR DIFFERENT QUANTITIES OF FLOW.

GALLONS PER MINUTE.	INTERNAL DIAMETER OF PIPES IN INCHES.							
	¾	1	1¼	1½	2	2½	3	4
5	218	122½	78½	54½	30½	19½	13½	7⅔
10	436	245	157	109	61	38	27	15⅓
15	653	367½	235½	163½	91½	58½	40½	23
20	872	490	314	218	122	78	54	30⅔
25	1090	612½	392½	272½	152½	97½	67½	38⅓
30		735	451	327	183	117	81	46
35		857½	549½	381½	213½	136½	94½	53⅔
40		980	628	436	244	156	108	61⅛
45		1102½	706½	490½	274½	175½	121½	69
50			785	545	305	195	135	76⅔
75			1177½	817½	457½	292½	202½	115
100				1090	610	380	270	153⅓
125					762½	487½	337½	191⅔
150					915	585	405	230
175					1067½	682½	472½	268⅓
200					1220	780	540	306⅔

QUANTITY OF WATER PER LINEAL FOOT IN PUMPS OR VERTICAL PIPES OF DIFFERENT DIAMETERS.

DIAMETER OF PUMP OR PIPE IN INCHES	NUMBER OF GALLONS PER LINEAL FOOT.	NUMBER OF CUBIC FEET PER LINEAL FOOT.	DIAMETER OF PUMP OR PIPE IN INCHES.	NUMBER OF GALLONS PER LINEAL FOOT.	NUMBER OF CUBIC FEET PER LINEAL FOOT.
2	·136	·0218	8	2·176	·3490
2¼	·172	·0276	8¼	2·314	·3712
2½	·212	·0340	8½	2·456	·3940
2¾	·257	·0412	8¾	2·603	·4175
3	·306	·0490	9	2·754	·4417
3¼	·359	·0576	9¼	2 909	·4666
3½	·416	·0688	9½	3·068	·4923
3¾	·478	·0766	9¾	3·232	·5184
4	·544	·0872	10	3·400	·5454
4¼	·614	·0985	10¼	3·572	·5730
4½	·688	·1104	10½	3·748	·6013
4¾	·767	·1230	10¾	3·929	·6302
5	·850	·1363	11	4·114	·6599
5¼	·937	·1503	11¼	4·303	·6902
5½	1·028	·1649	11½	4·496	·7212
5¾	1·124	·1803	11¾	4·694	·7529
6	1·224	·1963	12	4·896	·7853
6¼	1·328	·2130	12½	5·312	·8521
6½	1·436	·2304	13	5·746	·9217
6¾	1·549	·2489	13½	6·196	·9939
7	1·666	·2672	14	6·664	1·0689
7¼	1·787	·2866	15	7·650	1·2271
7½	1·912	·3067	16	8·704	1·3962
7¾	2·042	·3275	18	11·016	1·7670

TABLES OF CAPACITIES OF PUMPS IN CUBIC INCHES AND GALLONS.

Diameter in inches.	Length of Stroke in Inches.																			
	1		2		3		4		5		6		7		8		9		10	
	C. Ins.	Gals.	C. Ins.	Gals.	C. Ins.	Gals.	C. Ins.	Gals.	C. Ins.	Gals.	C. Ins.	Gals.	C. Ins.	Gals.	C. Ins.	Gals.	C. Ins.	Gals.	C. Ins.	Gals.
1	·785	·0028	1·571	·0056	2·356	·0085	3·141	·0113	3·927	·0141	4·712	·0169	5·498	·0198	6·283	·0226	7·068	·0254	7·854	·0283
1½	1·767	·0063	3·534	·0127	5·301	·0191	7·068	·0255	8·835	·0318	10·602	·0382	12·370	·0509	14·137	·0573	15·905	·0637	17·672	·0701
2	3·141	·0113	6·283	·0226	9·425	·0340	12·566	·0453	15·708	·0566	18·849	·0679	21·991	·0793	25·132	·0906	28·274	·1019	31·416	·1133
2½	4·908	·0177	9·817	·0354	14·726	·0532	19·634	·0709	24·543	·0886	29·452	·1064	34·360	·1241	39·269	·1418	44·178	·1595	49·087	·1773
3	7·068	·0255	14·137	·0510	21·206	·0764	28·274	·1019	35·343	·1274	42·411	·1529	49·489	·1784	56·549	·2039	63·617	·2294	70·686	·2549
4	12·566	·0453	25·132	·0906	37·698	·1359	50·265	·1813	62·830	·2266	75·396	·2719	87·962	·3172	100·53	·3625	113·09	·4079	125·66	·4532
5	19·635	·0708	39·270	·1416	58·905	·2124	78·540	·2832	98·175	·3540	117·81	·4248	137·44	·4956	157·08	·5665	176·71	·6373	196·35	·7081
6	28·274	·1019	56·548	·2039	84·822	·3059	113·09	·4079	141·37	·5098	169·64	·6118	197·92	·7138	226·19	·8157	254·46	·9177	282·74	1·0197
7	38·484	·1388	76·968	·2776	115·45	·4164	153·93	·5552	192·42	·6940	230·90	·8328	269·39	·9716	307·87	1·1104	346·35	1·2492	384·84	1·3880
8	50·265	·1812	100·53	·3625	150·79	·5438	201·06	·7251	251·32	·9064	301·59	1·0877	351·85	1·2689	402·12	1·4502	452·38	1·6315	502·65	1·8128
9	63·617	·2294	127·23	·4589	190·85	·6883	254·47	·9178	318·08	1·1472	381·70	1·3767	445·32	1·6061	508·93	1·8356	572·55	2·0650	636·17	2·2945
10	78·540	·2832	157·08	·5665	235·62	·8497	314·16	1·133	392.70	1·4163	471·24	1·6995	549·78	1·9828	628·32	2·2660	706·86	2·5493	785·40	2·8326
11	95·033	·3427	190·06	·6854	285·09	1·0281	380·13	1·3708	475·16	1·7135	570·19	2·0562	665·23	2·3989	760·26	2·7416	855·29	3·0843	950·33	3·4270
12	113·09	·4078	226·18	·8156	339·27	1·2234	452·36	1·6312	565·45	2·0390	078·54	2·4468	791·63	2·8546	904·72	3·2624	1007·8	3·6702	1120·9	4·0780
13	132·73	·4787	265·46	·9574	398·19	1·4361	530·92	1·9148	663·65	2·3935	796·38	2·8722	929·11	3·3509	1061·8	3·8296	1194·5	4·3083	1327·2	4·7870
14	153·93	·5552	307·86	1·1104	461·79	1·6656	615·72	2·2208	769·65	2·7760	923·58	2·3312	1077·5	3·8864	1231·4	4·4416	1385·3	4·9968	1539·3	5·5520
15	176·71	·6373	353·42	1·2746	530·13	1·9119	706·84	2·5492	883·55	3·1865	1060·2	3·8238	1236·9	4·4611	1413·6	5·0984	1590·3	5·7357	1767·1	6·3730
16	201·06	·7251	402·12	1·4502	603·18	2·1753	804·24	2·9004	1005·3	3·6255	1206·3	4·3506	1407·4	5·0757	1608·4	5·8008	1809·5	6·5259	2010·6	7·2510
17	226·98	·8186	453·96	1·6372	680·94	2·4558	907·92	3.2744	1134·9	4·0930	1361.8	4·9116	1588·8	5·7302	1815·8	6·5488	2042·8	7·3674	2269·8	8·1860
18	254·46	·9177	508·92	1·8354	763·48	2·7531	1017·8	3·6708	1272·3	4·5885	1526·7	5.5062	1781·2	6·4239	2035·6	7·3416	2290·1	8·2593	2544·6	9·1770
19	283·52	1·0225	567·04	2·0450	850·56	3·0675	1134·0	4·0900	1417·6	5·1125	1701·1	6·1350	1984·6	7·1575	2268·1	8·1800	2551·6	9·2025	2835·2	10·225
20	314·16	1·1330	628·32	2·2660	942·48	3·3990	1256·6	4·5320	1570·8	5·6650	1884·9	6·7980	2199·1	7.9310	2513·2	9·0640	2827·4	10·197	3141·6	11·330
22	380·13	1·3709	760·26	2·7418	1140·4	4·1127	1520·5	5·4836	1900·6	6·8545	2280·8	8·2254	2660·9	9·5963	3041·0	10·967	3421·1	12·338	3801·3	13·709
24	452·39	1·6315	904·78	3·2630	1357·1	4·8945	1809·5	6·5260	2261·9	8·1575	2714·3	9·7890	3166·7	11·420	3619·1	13·052	4071·5	14·683	4523·9	16·315
26	530·93	1·9148	1061·8	3·8296	1592·7	5·7444	2123·7	7·6592	2654·6	9·5740	3185·5	11·488	3716·5	13·403	4247·4	15·318	4778·3	17·233	5309·3	19·148
28	615·75	2·2207	1231·5	4·4414	1847·2	6·6621	2463·	8·8828	3078·7	11·103	3694·5	13·324	4310·2	15·544	4926·	17·765	5541·7	19·986	6157·5	22·207
30	706·86	2·5493	1413·7	5·0986	2120·5	7·6479	2827·4	10·197	3534·3	12·746	4241·1	15·295	4948·	17·845	5654·8	20·394	6361·7	22·943	7068·6	25·493
32	804·24	2·9004	1608·4	5·8008	2412·7	8·7012	3216·9	11·601	4021·2	14·502	4825·4	17·402	5629·6	20·302	6433·9	23·203	7238·1	26·103	8042·4	29·004
34	907·92	3·2744	1815·8	6·5480	2723·7	9·8232	3631·6	13·097	4539·6	16·372	5447·5	19·646	6355·4	22·920	7263·3	26·195	8171·2	29·469	9079·2	32·744
36	1017·8	3·6710	2034·1	7·3420	3051·2	11·013	4068·3	14·684	5085·4	18·355	6102·4	22·026	7119·5	25·697	8136·6	29·368	9153·7	33·039	1017·0	36·710

TABLE OF CAPACITIES OF PUMPS IN CUBIC INCHES AND GALLONS—*continued.*

Diameter in inches.	Length of Stroke in Inches.																			
	11		12		13		14		15		16		18		20		22		24	
	C. Ins.	Gals.	C. Ins.	Gals.	C. Ins.	Gals.	C. Ins.	Gals.	C. Ins.	Gals.	C. Ins.	Gals.	C. Ins.	Gals.	C. Ins.	Gals.	C. Ins.	Gals.	C. Ins.	Gals.
1	8·639	·0311	·9425	·0339	10·110	·0368	10·995	·0396	11·781	·0424	12·566	·0452	14·137	·0509	15·708	·0566	17·279	·0622	18·849	·0679
1½	9·439	·0764	21·206	·0828	22·973	·0892	24·740	·0955	26·507	·1019	28·275	·1083	31·809	·1210	35·343	·1337	38·877	·1465	42·411	·1592
2	34·557	·1246	37·699	·1359	40·841	·1473	43·982	·1586	47·124	·1699	50·265	·1813	56·549	·2039	62·832	·2266	69·113	·2492	75·399	·2719
2½	53·995	·1950	58·904	·2127	63·813	·2305	68·721	·2482	73·630	·2659	78·539	·2836	88·356	·3191	98·174	·3546	107·99	·3900	117·81	·4255
3	77·754	·2804	84·823	·3059	91·892	·3313	98·960	·3568	106·03	·3823	113·09	·4078	127·23	·4588	141·37	·5098	155·51	·5608	169·64	·6117
4	138·22	·4985	150·79	·5438	163·36	·5891	175·92	·6345	188·49	·6798	201·05	·7251	226·19	·8157	251·32	·9064	276·55	·9970	301·58	1·0877
5	215·98	·7789	235·62	·8497	255·25	·9205	274·89	·9913	294·52	1·0321	314·16	1·1329	353·43	1·2746	392·70	1·4162	431·97	1·5578	471·24	1·6994
6	311·01	1·1216	309·29	1·2236	367·56	1·3256	395·83	1·4276	424·11	1·5295	452·31	1·6315	508·93	1·8354	565·48	2·0394	622·03	2·2433	678·57	2·4473
7	423·32	1·5268	461·81	1·6655	500·29	1·8043	538·77	1·9431	577·26	2·0819	615·74	2·2207	692·71	2·4983	769.68	2·7760	846·65	3·0534	923·61	3·3310
8	552·91	1·9941	603·18	2·1754	653·44	2·3566	703·71	2·5379	753·97	2·7192	804·24	2·9005	904·77	3·2630	1005·3	3·6256	1105·8	3·9882	1206·3	4·3508
9	699·78	2·5239	763·40	2·7534	827·02	2·9828	890·63	3·2123	954·25	3·4417	1017·8	3·6712	1145·1	4·1301	1272·3	4·5890	1399·5	5·0478	1526·8	5·5065
10	863·94	3·1158	942·48	3·3991	1021·0	3·6823	1099·5	3·9656	1178·1	4·2489	1256·6	4·5321	1413·7	5·0986	1570·8	5·6652	1727·8	6·2317	1884·9	6·7982
11	1045·3	3·7697	1140·3	4·1126	1235·4	4·4553	1330·4	4·7980	1425·4	5·1407	1520·5	5·4834	1710·5	6·1688	1900·6	6·8542	2090·7	7·5396	2280·7	8·2250
12	1233·9	4·4858	1357·1	4·8941	1470·2	5·3019	1583·3	5·7097	1696·4	6·1175	1089·5	6·5253	2035·7	5·3409	2261·9	8.1565	2488·1	8·9721	2714·3	9·7877
13	1459·9	5·2657	1592·7	5·7442	1725·5	6·2229	1858·2	6·7016	1980·9	7·1803	2123·7	7·6590	2389·1	8·6164	2654·6	9·5738	2920·1	10·531	3185·5	11·488
14	1693·2	6·1072	1847·2	6·6617	2001·1	7·2169	2155·1	7·7721	2309·0	8·3273	2463·0	8·8825	2770·8	9·9929	3078·7	11·203	3386·6	12·313	3694·5	13·424
15	1943·8	7·0103	2120·5	7.6478	2297·2	8·2851	2474·0	8·9224	2650·7	9·5597	2827·4	10·197	3180·8	11·471	3534·3	12·746	3887·7	14·020	4241·1	15·295
16	2211·6	7·9761	2412·7	8·7016	2613·8	9·4267	2814·8	10·151	3015·9	10·876	3216·9	11·602	3619·1	13·052	4021·2	14·502	4423·3	15·952	4825·4	17·402
17	2496·8	9·0036	2723·7	9·8232	2650·7	10·641	3177·7	11·460	3404·7	12·279	3631·6	13·097	4085·6	14·734	4539·6	16·372	4993·5	18·009	5447·5	19·646
18	2799·0	10·094	3053·6	11·012	3308·0	11·930	3562·5	12·848	3817·0	13·765	4071·5	14.683	4580·4	16·519	5089·3	18·354	5598·3	20·189	6107·2	22·025
19	3118·7	11·247	3402·3	12·270	3685·8	13·292	3969·4	14·315	4252·9	15·337	4536·4	16·360	5103·5	18·405	5670·5	20·450	6237·6	22·495	6804·7	24·540
20	3455·7	12·463	3769·9	13·596	4084·0	14·729	4398·2	15·861	4712·4	11·995	5026·5	18·128	5654·8	20·394	6283·2	22·660	6911·5	24·926	7539·8	27·192
22	4181·4	15·079	4561·5	16·451	4941·7	17·821	5321·8	19·192	5701·9	20·563	6082·1	21·934	6842·3	24·676	7602.6	27·418	8362·9	30·160	9123·1	32·901
24	4976·2	17·946	5428·6	19·579	5881·0	21·210	6333·4	22·842	6785·8	24·473	7238·2	26·105	8143·0	29·361	9047·8	32·631	9952·5	35·894	10857	39·157
26	5840·2	21·062	6371·1	22·978	6902·0	24·892	7433·0	26·807	7963·9	28·722	8494.8	30·637	9556·7	34·466	10618	38·296	11680	42·126	12742	45·955
28	6773·2	24.427	7389·0	26·649	8004·7	28·869	8620·5	31·090	9236·3	33·311	9852·0	35·531	11083	39·973	12315	44·414	13546	48·856	14778	53·297
30	7775·4	28·042	8482·3	30·592	9189·1	33·141	9896·0	35·690	10602	38·239	11309	40·789	12723	45·887	14137	50·986	15550	56·787	16964	62·588
32	8846·6	31·904	9650·9	34·806	10455	37·706	11259	40·606	12063	43·507	12868	46·497	14576	52·208	16085	58·009	17693	63·810	19301	69·610
34	9987·1	36·018	10895	39·295	11802	42·569	12710	45·843	13618	49.118	14526	52·392	13642	58·941	18158	65·490	19974	72·039	21790	78·587
36	11187	40·381	12214	44·051	13232	47·722	14240	51·393	15258	55·064	16275	58·734	18311	66·076	20347	73·418	22383	80·760	24418	88·102

COMPARISON OF THERMOMETERS.

C	F	R	C	F	R	C	F	R	C	F	R
100	212	80	69	156·2	55·2	38	100.4	30·4	7	44·6	5·6
99	210·2	79·2	68	154·4	54·4	37	98·6	29·6	6	42·8	4·8
98	208·4	78·4	67	152·6	53·6	36	96·8	28·8	5	41	4
97	206·6	77·6	66	150·8	52·8	35	95	28	4	39·2	3·2
96	204·8	76·8	65	149	52	34	93·2	27·2	3	37·4	2·4
95	203	76	64	147·2	51·2	33	91·4	26·4	2	35·6	1·6
94	201·2	75·2	63	145·4	50·4	32	89·6	25·6	1	33·8	·8
93	199·4	74·4	62	143·6	49·6	31	87·8	24·8	0	32	0
92	197·6	73·6	61	141·8	48·8	30	86	24			
91	195·8	72·8	60	140	48	29	84·2	23·2			
90	194	72	59	138·2	47·2	28	82·4	22·4	— 1	+ 30·2	— ·8
89	192·2	71·2	58	136·4	46·4	27	80·6	21·6	— 2	+ 28·4	— 1·6
88	190·4	70·4	57	134·6	45·6	26	78·8	20·8	— 3	+ 26·6	— 2·4
87	188·6	69·6	56	132·8	44·8	25	77	20	— 4	+ 24·6	— 3·2
86	186·8	68·8	55	131	44	24	75·2	19·2	— 5	+ 23	— 4
85	185	68	54	129·2	43·2	23	73·4	18·4	— 6	+ 21·2	— 4·8
84	183·2	67·2	53	127·4	42·4	22	71·6	17·6	— 7	+ 19·4	— 5·6
83	181·4	66·4	52	125·6	41·6	21	69·8	16·8	— 8	+ 17·6	— 6·4
82	179·6	65·6	51	123·8	40·8	20	68	16	— 9	+ 15·8	— 7·2
81	177·8	64·8	50	122	40	19	66·2	15·2	—10	+ 14	— 8
80	176	64	49	120·2	39·2	18	64·4	14·4	—11	+ 12·2	— 8·8
79	174·2	63·2	48	118·4	38·4	17	62·6	13·6	—12	+ 10·4	— 9·6
78	172·4	62·4	47	116·6	37·6	16	60·8	12·8	—13	+ 8·6	—10·4
77	170·6	61·6	46	114·8	36·8	15	59	12	—14	+ 6·8	—11·2
76	168·8	60·8	45	113	36	14	57·2	11·2	—15	+ 5	—12
75	167	60	44	111·2	35·2	13	55·4	10·4	—16	+ 3·2	—12·8
74	165·2	59·2	43	109·4	34·4	12	53·6	9·6	—17	+ 1·4	—13·6
73	163·4	58·4	42	107·6	33·6	11	51·8	8·8	—18	— ·4	—14·4
72	161·6	57·6	41	105·8	32·8	10	50	8	—19	— 2·2	—15·2
71	159·8	56·8	40	104	32	9	48·2	7·2	—20	— 4	—16
70	158	56	39	102·2	31·2	8	46·4	6·4			

TO CONVERT DEGREES, CENTIGRADE OR REAUMUR, INTO DEGREES FAHRENHEIT.

Let F = No. of Degrees Fahrenheit. Let C = No. of Degrees Centrigrade.
Let R = No. of Degrees Reaumur.

$$F = \frac{9C}{5} + 32^\circ. \qquad F = \frac{9R}{4} + 32^\circ = C + R + 32^\circ.$$

$$C = \frac{5\ (F - 32)}{9} \qquad R = \frac{4\ (F - 32)}{9}$$

Example.—To convert 75° Centigrade into Fahrenheit.

$$F = \frac{(9 \times 75)}{5} + 32 = \frac{675}{5} + 32 = 167^\circ$$

To convert 113° Fahrenheit into Reaumur.

$$R = \frac{4\ (113 - 32)}{9} = \frac{324}{9} = 36^\circ$$

Freezing Point, or 32° Fah. = Zero in Cent. and Reaumur.
Boiling Point, or 212° Fah. = 100° Cent. or 80° Reaumur.

(*Tangye.*)

ELECTRICAL MEASURES AND POWERS.

The following definitions of the principal terms relating to electrical energy, may be useful to those who are not familiar with them.

VOLTS, POTENTIAL, OR ELECTRO MOTIVE FORCE (E.M.F.) as commonly used as equivalent terms signifying **pressure** of current, and convey the same idea as lbs. per square inch when dealing with steam pressure.

CURRENT OR AMPÈRES indicate the **quantity** of electric current transmitted by a wire or cable, and conveys the same idea as gallons of water, or cubic feet of gas passed through a pipe.

OHM is the unit representing **resistance** and corresponds (practically) with the term "frictional loss" which causes reduced terminal pressure of liquids in their passage through pipes.

WATTS represent the product of current in Ampères and pressure in volts, thus: 100 Ampères at 210 volts = 21,000 Watts, and serves the same purpose in calculations for electrical transmission of energy, as foot-pounds do in estimating horse power.

KILOWATT (K.W.) is 1000 Watts, or about $1\frac{1}{2}$ horse-power.

BOARD OF TRADE UNIT, written B.T.U. or Unit, each representing electrical energy equal to 1000 Watt-hours.

EFFECTIVE HORSE-POWER OF MOTORS.—The efficiency of the motor at the point at which it is worked having been ascertained, the effective horse-power is obtained by multiplying the volts and ampères, as measured at the terminals of the motor, and dividing them by 746, the whole being then multiplied by the efficiency.

Thus, supposing the efficiency = 90 per cent. and the motor consumes 100 volts and 50 ampères, effective horse-power = $\frac{100 \times 50}{746} \times \cdot 90 =$ (say) 6·03 horse-power.

POWER OF DYNAMO.—746 Watts = 1 electrical H.P. therefore, taking the above figures and assuming an efficiency of 80 per cent. we have $\frac{21000}{746} \times \frac{100}{80}$ 35·18 = the brake H.P. of the Dynamo.

DRIVING POWER REQUIRED.—The brake H.P. of engines being usually 10 to 15 per cent. less than the indicated H.P. the engine to drive a dynamo producing the above-named 35·18 brake H.P. should develop about 40 indicated H.P.

CONTROLLERS.—The two principal types of controllers are based respectively on metallic and liquid resistance. The former is undoubtedly the most suitable for regulating the speed of Motors and—for that reason—is principally employed by the writer's firm.

Metallic Controllers.—A very large area of metal with high metallic resistance and large cooling surface, is compactly arranged in a frame on one face of which is a switch-head with regulating handle. The resistance is divided into a convenient number of steps each step having its corresponding terminal on the face of the switch. By moving the handle over the terminal points, the requisite resistance is put into the motor circuit and the speed of the motor thereby regulated.

CONDUCTORS.—The conditions under which current is most conveniently conveyed to motors vary considerably, but one or other of those now referred to, will probably be suitable.

Overhead wires with collecting trolley, are quite satisfactory for most machines, but less so for Cranes with long jibs on account of the great height of the trolley wire above ground level.

The conduit system is usually best adapted for supplying current to Cranes with high jibs, and specially to those which have electric travelling motion, the current being conveyed to the motor by cables passing through the central pivot.

Auxiliary rails laid between the track rails are sometimes used, as indicated in Fig. 5032, but this system cannot be advocated if the voltage is high, and the conductor rails cannot be completely protected.

FRACTIONAL PARTS OF A YARD AND FOOT WITH EQUIVALENT DECIMAL PARTS.

DECIMAL. PART.	CORRESPONDING FRACTIONAL PART.	VALUE OF DECIMAL OR FRACTIONAL PART REFERRED TO A YARD.		A FOOT.
		FEET.	INS.	INCHES.
·031	$\frac{1}{32}$		$1\frac{1}{8}$	$\frac{3}{8}$
·062	$\frac{1}{16}$		$2\frac{1}{4}$	$\frac{3}{4}$
·093	$\frac{3}{32}$		$3\frac{3}{8}$	$1\frac{1}{8}$
·125	$\frac{1}{8}$		$4\frac{1}{2}$	$1\frac{1}{2}$
·156	$\frac{5}{32}$		$5\frac{5}{8}$	$1\frac{7}{8}$
·187	$\frac{3}{16}$		$6\frac{3}{4}$	$2\frac{1}{4}$
·217	$\frac{7}{32}$		$7\frac{7}{8}$	$2\frac{5}{8}$
·250	$\frac{1}{4}$		9	3
·281	$\frac{9}{32}$		$10\frac{1}{8}$	$3\frac{3}{8}$
·312	$\frac{5}{16}$		$11\frac{1}{4}$	$3\frac{3}{4}$
·343	$\frac{11}{32}$	1	$0\frac{3}{8}$	$4\frac{1}{8}$
·375	$\frac{3}{8}$	1	$1\frac{1}{2}$	$4\frac{1}{2}$
·405	$\frac{13}{32}$	1	$2\frac{5}{8}$	$4\frac{7}{8}$
·437	$\frac{7}{16}$	1	$3\frac{3}{4}$	$5\frac{1}{4}$
·468	$\frac{15}{32}$	1	$4\frac{7}{8}$	$5\frac{5}{8}$
·500	$\frac{1}{2}$	1	6	6
·531	$\frac{17}{32}$	1	$7\frac{1}{8}$	$6\frac{3}{8}$
·561	$\frac{9}{16}$	1	$8\frac{1}{4}$	$6\frac{3}{4}$
·592	$\frac{19}{32}$	1	$9\frac{3}{8}$	$7\frac{1}{8}$
·624	$\frac{5}{8}$	1	$10\frac{1}{2}$	$7\frac{1}{2}$
·656	$\frac{21}{32}$	1	$11\frac{5}{8}$	$7\frac{7}{8}$
·687	$\frac{11}{16}$	2	$0\frac{3}{4}$	$8\frac{1}{4}$
·718	$\frac{23}{32}$	2	$1\frac{7}{8}$	$8\frac{5}{8}$
·750	$\frac{3}{4}$	2	3	9
·781	$\frac{25}{32}$	2	$4\frac{1}{8}$	$9\frac{3}{8}$
·812	$\frac{13}{16}$	2	$5\frac{1}{4}$	$9\frac{3}{4}$
·843	$\frac{27}{32}$	2	$6\frac{3}{8}$	$10\frac{1}{8}$
·874	$\frac{7}{8}$	2	$7\frac{1}{2}$	$10\frac{1}{2}$
·906	$\frac{29}{32}$	2	$8\frac{5}{8}$	$10\frac{7}{8}$
·937	$\frac{15}{16}$	2	$9\frac{3}{4}$	$11\frac{1}{4}$
·968	$\frac{31}{32}$	2	$10\frac{7}{8}$	$11\frac{5}{8}$

FOR DECIMAL EQUIVALENTS OF 1 INCH see table, Inches=Millimetres, p. 299.

DECIMAL EQUIVALENTS OF POUNDS AND OUNCES (AVOIRDUPOIS).

Ounce	$\frac{1}{2}$	$\frac{3}{4}$	1	2	3	4	5	6	7
Decimal of Pound ...	·031	·047	·063	·125	·188	·250	·312	·375	·438
Ounce	8	9	10	11	12	13	14	15	16
Decimal of Pound ...	·500	·563	·625	·688	·750	·812	·875	·938	1

DISTANCES AND TELEGRAPHIC RATES BETWEEN LONDON AND OTHER PORTS.

Where there are two sailing routes, or two routes and rates for telegrams, both are given, that standing first being the more largely used.

Rates for British Ports are left blank, these being subject to the ordinary Inland rate of 6d. per 12 words, and one halfpenny for each additional word.

European telegrams.—The minimum charge is 10d. reckoned at the rates in the tables, and code words are not transmitted in several countries.

DISTANCE FROM LONDON.	NAUTICAL MILES.	TELEGRAMS PER WORD.
Aberdeen	433	..
Aden	4,695 9,955	3/-
Alexandria	3,095	1/7
Amsterdam	333	2d.
Antwerp	182	2d.
Archangel	2,226	5½d.
Auckland, N.Z.	10,916 12,120	3/4, 3/1
Barbadoes	3,795	4/9
Barcelona	1,902	3½d. 5½d.
Batavia (Java)	8,330 11,270	4/-, 3/10
Bombay	6,330 10,595	2/6, 3/8
Bordeaux	650	2d.
Boston, U.S.A	3,025	1/-
Brisbane	12,148 11,670	3/-, 2/10
Bristol	534	..
Buenos Ayres	6,280	4/2, 3/11
Cadiz	1,322	3½d. 5½d.
Calcutta	7,950 11,450	2/6, 3/8
Canton	10,468 13,553	5/6, 5/9
Cape of Good Hope	6,065	3/-
Cape Horn	7,395	..
Cardiff	517	..
Charlestown, U.S.A.	3,695	1/3
Colombo (Ceylon)	6,795 10,885	2/7, 3/9
Constantinople	3,085	6½d. 11d.
Copenhagen	708	3d.
Cork (Queenstown)	551	..
Delagoa Bay	7,292	3/1
Durban	6,993	3/-
Dundee	420	..
Ferrol	785	3½d. 5½d.
Freemantle, W.A.	10,428 11,630	3/-, 2/10
Funchal (Madeira)	1,397	1/-
Gibraltar	1,330	3½d.
Glasgow	735	..
Halifax, N.S.	2,692	1/-
Hamburg	418	2d.
Havanna	4,229	2/5
Hobart Town	10,291 11,495	3/-, 2/10
Hong Kong	9,775 12,910	5/6
Kingston (Jamaica)	3,968	3/-
Leghorn	2,258	3d.
Leith	418	..
Lima	10,655	5/9
Lisbon	1,053	3½d.
Liverpool	660	..
Lizard	347	..
Madras	7,330 10,830	2/6, 3/8
Malacca	8,737 12,237	3/6, 3/4
Malta	2,310	6d.
Manilla	9,650	5/9
Mauritius	7,005	3/-
Melbourne	11,250 11,635	3/- 2/10
New Orleans	4,687	1/3
New York	3,245	1/-
Noumea	13,480	3/8, 3/6
Odessa	3,409	5½d.
Otago	12,190	3/4, 3/1
Pekin (Gulf)	11,925 15,060	5/6
Pernambuco	4,130	3/-
Plymouth	315	..
Port Jackson	11,817 13,021	3/-, 2/10
Pulo Penang	8 858 11,993	3/6, 3/4
Quebec	2,930	1/-
Rangoon	8 025 11,530	2/6, 3/10
Rio Janeiro	5,200	4/-
Rotterdam	185	2d.
San Francisco	13,670	1/6
Shanghai	10,545 13,630	5/6
Shields	315	..
Sierra Leone	2,927	4/6
Singapore	8,345 11,670	3/6, 3/4
St. Helena	4,525	3/-
St Jago (Cape Varde Island)	2,672	3/1
St. John (New Foundland)	2,099	1/-
St. Petersburg	1,587	5½d.
Stockholm	1,108	3½d.
Sydney	10,840 12,044	3/-, 2/10
Teneriffe	1,730	9d.
Valparaiso	9,071	5/9
Venice	3,195	3d.
Vira Cruz (Mexico)	5,070	2/6
Washington	3,850	1/6
Waterford	608	..
Yokohama	11,345 14,578	6/2, 7/9
Zanzibar	6,336	

PRINCIPAL BRITISH WEIGHTS, MEASURES AND COINAGE,

WITH EQUIVALENTS IN FOREIGN STANDARDS.

GREAT BRITAIN AND COLONIES.	FRANCE (METRIC).	CHINA.	INDIA.	JAPAN.	RUSSIA.	EGYPT.
Weights.						
1 ounce	28·35 grammes	—	—	7·555 momme	—	—
1 lb. (16 oz.) ..	0·4534 kilos.	12 taels	0·5 sihrs	126·958 ,,	1·10 funt	1 rotola
1 quarter (28 lbs.) ..	12·695 ,,	21 catties	15·0 ,,	3·386 kwan	31·00 ,,	0 28 cantare
1 cwt. (112 lbs.) ...	50·803 ,,	84 catties	1 mo 20 sihrs	13·547 ,,	3 pood 4 funt	1·14 ,,
1 ton (20 cwt. ..	1016·000 ,,	16 picols 80 catties	30 maund	270·945 ,,	62·1 pood	22·4 ,,
Lineal Measure.						
1 foot (12 inches) ...	0·305 metres	81 decimals	16 angli	1 shaku	0·7 vershok	0·52 piks beledi
1 yard (3 feet) ...	0·915 ,,	2 cricks 45 decimals	1 gus	3 017 shaku	1 arsh 5 versch	1·56 ,, ,,
1 mile (1760 yards) ...	1609·315 ,,	2·8 li	0·875 mile	5309·92 ,,	1 werst 260 sachen	27·62 ,, ,,
Square Measure.						
1 square inch ...	0·0071 sq. metres	—	—	—	—	—
1 square foot (144 inches)	0·0929 ,,	—	—	—	—	—
1 square yard (9 feet) ..	0·836 ,,	—	—	—	—	—
Cubic Measure.						
1 cubic inch	16·38 cubic cm.	—	—	—	—	—
1 cubic foot	0·0283 cub. metre	—	—	—	—	—
1 cubic yard (27 feet) ..	0·7645 ,, ,,	—	—	—	—	—
Liquid Measure.						
1 quart (2 pints) ...	1·14 litres	by weight	1·215 ser	6·15 go	923 krushka	0·27 keles
1 gallon (4 quarts) ...	4·54 ,,	,,	4·861 ,,	2·52 sho	3·692 ,,	1·10 ,,
Money.						
1 shilling (12 pence) ...	1·26 frances	0·372 taels	12 annas	475 sen	47 copeks	4·88 piattres
1 pounds sterling (20s.)	25·24 ,,	7·44 ,,	15 rupees	9·5 yen	9·45 roubles	97·75 ,,

SQUARE AND CUBIC MEASURES.—British or Metric Standards (principally British) are employed by Engineers in the above-named countries where these measurements are omitted.

UNITED STATES OF AMERICA AND THE DOMINION OF CANADA.—The weights and measures are (practically) the same as British, excepting that a *Ton of 2000 lbs.* is often used and *U.S.A. Quarts and Gallons* are ·833 of Standard British measures.

Coinage.—100 cents. = 1 dollar; 4·86 dollars = £1; and 24 cents. = 1s.

THE METRIC SYSTEM of weights and measures (as in France) is adopted in the undernamed countries, and the equivalent values of their currencies are approximately, as follows:—

RELATIVE VALUE OF CURRENT COINS.

GREAT BRITAIN AND COLONIES.	1 POUND STG. (£)	1 SHILLING (1s.)
Argentine	11¾ dollars	56 cents.
Austria	24·12 krone	120 heller
Brazil ...	30·11 millereis	1 mr. 505 reis
Belgium	25·24 francs	1·26 francs
Chili ...	15¼ dollars	...
Denmark ...	18·22 krone	0·91 krone
Germany ...	20·47 marks	1·02 mark
Holland ...	12·10¼ florin	0·60 florin
Italy ...	27.15 lire	1·35 lire
Mexico ...	4·86 dollars	24 cents.
Norway ...	18·22 krone	0·91 krone
Peru	10 dollars	84 cents.
Portugal ...	6·55 millereis	327 reis
Roumania	25·00 francs	1·25 francs
Spain ..	31 pesetas	1·55 pesetas
Sweden ...	18·22 krone	0·91 krone
Switzerland	25·24 francs	1·26 francs
Uruguay	4·70 dollars	23½ cents.

The rates of exchange given in this table may be regarded as the average of a long period, fluctuating, however, from day to day.

BRITISH COINAGE AND STANDARDS.

GOLD COINS (22 carat) contain 916·6 parts of gold and 83·4 parts of silver, therefore about 916⅔rds fine and costs £3 17s. 10½d. per ounce Troy.

20 lbs. Troy of standard gold is coined into 934½ sovereigns, therefore 1 oz. Troy of pure gold is worth £4 4s. 11½d.

SILVER COINS (·925 fine) contain 925 parts of silver, and 75 parts of copper, and 1 lb. Troy is coined into 66 shillings or other silver coins representing a value of £3 6s.

The price of silver has ranged from about 45/- per lb. Troy in 1891 to less than 24/- per lb. in 1902.

BRONZE COINS contain 95 parts of copper, 4 of tin and 1 of zinc, and 1 lb. Avoirdupois is coined into 40 pence or 80 half-pence. The price of copper varies very widely.

STANDARD WEIGHT, ETC. OF CURRENT COINS.

DENOMINATION.		WEIGHT. GRAINS.	APPROX. DIAM. INCH.	APPROX. DIAM. M/M.
Sovereign (£1)	Gold	123·274	⅞	22·22
Half Sovereign (10/-)	,,	61·637	¾	19·05
Crown (5/-)	Silver	436·364	1½	38·09
Half Crown (2/6)	,,	218·182	1¼	31·75
Florin (2/-)	,,	174·546	1 5/32	28·57
Shilling (1/-)	,,	87·273	15/16	23·81
Sixpence (6d.)	,,	43·636	¾	19·05
Threepence (3d.)	,,	21·818	⅝	15·88
Penny (1d.)	Bronze	145·833	1 3/16	30·16
Half Penny (½d.)	,,	72·916	1	25·40

SPECIFIC GRAVITIES, WEIGHTS AND PROPERTIES OF MATERIALS.

The following tables of weights per cubic foot of different materials will be useful in estimating cost of freight, the power required for hoisting or hauling given quantities of them and for other purposes.

In estimating cost of freight, it should be remembered that materials weighing less than 56 lbs. per cubic foot are carried at measurement rates (usually) 40 cubic feet = 1 ton.

MATERIALS	SPECIFIC GRAVITY.	WEIGHT OF A CUBE FOOT IN LBS.	WEIGHT OF A CUBE INCH IN LBS.	TENACITY IN LBS. PER SQUARE INCH.	CRUSHING FORCE IN LBS. PER SQUARE INCH.
METALS—					
Aluminium	2·56	160·	·092		
Antimony, Cast	6·7	418·9	·242	1066	
Arsenic	5·76	360·2	·208		
Bismuth, Cast	9·82	615·	·356	3250	
Brass, Cast	8·4	525·	·303	17978	10300
Brass Wire	8·5	531·	·307	49000	
Bronze	8·22	513·4	·297		
Cobalt, Cast	7·81	488·2	·282		
Copper, Cast	8·89	555·	·321	19072	11700
Copper, Sheet	8·95	559	·323	33000	
Copper Wire	9·	562	·325	61000	
Gold, Pure	19·25	1203·6	·7	20400	
Gold, Hammered	19·36	1210·1	·7		
Gold, Standard	17·64	1102·9	·638		
Gun Metal	8·4	525·	·303	36000	
Iron, Wrought (Bar)	7·7	481·	·28	60000	38000
Iron, Swedish	7·6	475	·275	70000	
Iron Wire				85000	
Iron, Cast	7·18	448·	·259	19000	92000
Lead, Cast	11·38	709·	41	1824	7000
Lead, Sheet				3328	
Mercury, Solid	15·63	977·	·565		
Mercury, Fluid	13·56	848·	·49		
Nickel, Cast	7·8	487·9	·282		
Platinum, Pure	19·5	1218·8	·705		
Platinum, Hammered	20·33	1271·	·735		
Silver, Pure	10·47	654·6	·38	41000	
Silver, Hammered	10·51	656·9	·38		
Silver, Standard	10·53	658·4	·381		
Steel, Tempered	7·81	488·6	·282	120000	
Steel, Soft	7·83	489·6	·283	43000	
Steel, Puddled	7·78	485·	282	80000	
Tin, Cast	7·29	455·7	·262	5000	15000
Type Metal	10·45	653·1	·378		
Zinc	7·	437·	·253	8000	
STONES, EARTHS, &c.—					
Basaltes	27·22	170·1	1		
Borax	17·14	107·1	·062		
Brick	2·	124·	·071	290	1500
Brickwork in Mortar	1·6	100	·058	50	
Brickwork in Cement	1·8	112 to 94·	·062	290	1000
Concrete, Ordinary	1·9	119·	·069		
Concrete in Cement	2·2	133·	077		
Cement, Portland	1·3	81·	048	2	1000
Cement, Roman	1·	63·	·036		
Chalk	2·3	143·	082		400
Clay	2·	125	·071		
Coal	1·3	82·	·048		
Coke	·8	50·	·029		
Cutler's Stone	2·11	131·9	·076		
Emery	4·	250·	·144		
Earth, Rammed	1·6	100·	·058		
Flint	2·6	163·	·094		
Freestone	2·45	153·3	·089		
Gypsum	2·17	135·5	·078		
Granite (mean of fourteen sorts)	2·69	168·6	·097		8000
Grindstone	2·14	133·9	·077		
Limestone	2·94	184·1	·11		3000 to 8000

PROPERTIES, &c. OF MATERIALS—*continued.*

MATERIALS.	SPECIFIC GRAVITY.	WEIGHT OF A CUBE FOOT IN LBS.	WEIGHT OF A CUBE INCH IN LBS.	TENACITY IN LBS. PER SQUARE INCH.	CRUSHING FORCE IN LBS. PER SQUARE INCH.
STONES, EARTHS, &c.—*continued.*					
Marble (mean of nineteen sorts)	2·72	170·	·1	6000	6000
Millstone	2·48	155·3	·089		
Peat, Hard	1·32	83·1	·049		
Porphyry	2·72	170·2	·1		
Pumice Stone	·915	57·2	·033		
Purbeck Stone	2·6	162·6	·094		
Rag Stone	2·47	154·4	·089		
Rotten Stone	1·98	123·8	·071		
Salt	2·13	133·1	·077		
Sand	1·9	120·	·07		
Sandstone	2·5	156·	·089		5000
Slate	2·8	175·	·1	9000	11000
Stone, Bath	1·8	112·	·065		
Stone, Common	2·52	157·5	·091		
Stone, Portland	2·57	160·1	·092		
Shingle	1·4	90·	·052		
Sulphur, Native	2·03	127·1	·073		
Sulphur, Melted	1·99	124·4	·072		
WOODS—					
Acacia and Orange Tree ..	·71	44·4	·025		
Ash and Dantzic Oak ..	·76	50·	·029	17200	9000
Beech	·7	43·8	·025	11000	9000
Birch, Common	·7	43·8	·025	15000	5500
Birch, American Black ..	·75	46·9	·027		
Box and Greenheart	1·	62·5	·036		
Cedar	·48	31·	·018	11000	5600
Cherry Tree	·715	44·7	·025		
Cork	·24	15·	·009		
Deal, Christiana	·68	43·	·025	12000	6000
Deal, Memel	·39	36·9	·021		
Ebony	1·27	79·4	·046		
Elm and Larch	·54	33·8	·019	13000	10000
Fir, New England	·55	34·4	·02		
Fir, Riga, and Maple ..	·75	46·9	·027		
Fir, Mar Forest	·70	43·8	·025		
Hornbeam	·75	47·	·027	20000	7000
Lignum Vitæ	1·33	83·3	·049		
Logwood	·913	57·1	·033		
Mahogany, Spanish	·8	50·	·029	16000	8000
Norway Spars	·58	36·3	·021		
Oak, English	·93	58·	·033	17000	10000
Oak, Canadian	·87	54·5	·032	10000	6000
Oak, African	·98	61·3	·035		
Oak, Adriatic	·99	61·9	·036		
Pear Tree	·646	40·4	·023		
Pine, Red	·65	41·	·023	12000	5800
Pine, Yellow	·45	29·	·016	11000	5400
Poon and Hazel	·6	37·5	·021		
Poplar	·456	28·5	·016		
Plum Tree	·75	46·9	·027		
Teak, Moulmein	·65	41·	·023	15000	12000
Walnut	·67	41·9	·023		
Willow	·585	36·6	·021	8000	
Yew	·798	49·9	·028		
GASES, LIQUIDS, &c.—					
Atmospheric Air	·0012	·075			
Azotic Gas	·00118	·074			
Carbonic Acid Gas	·00182	·614			
Muriatic Acid Gas	·00153	·096			

PROPERTIES, &c. OF MATERIALS—*concluded.*

MATERIALS	SPECIFIC GRAVITY.	WEIGHT OF A CUBE FOOT IN LBS.	WEIGHT OF A CUBE INCH IN LBS.
GASES, LIQUIDS, &c.—*continued*			
Nitric Acid Gas	·00291	·182	
Sulphurous Acid Gas	·00276	·172	
Hydrogen Gas	·0001	·006	
Oxygen Gas	.00143	·09	
Acid, Acetic	1·063	66·4	·038
Acid, Muriatic	1·2	75·	·043
Acid, Nitric	1·271	79·4	·046
Acid, Phosphoric	1·558	97·4	·056
Acid, Sulphuric	1·85	115·6	·067
Alcohol, Absolute	·797	49·8	·029
Alcohol, Highly Rectified	·829	51·8	·03
Alcohol of Commerce	·837	52·3	·03
Ammoniac, Liquid	·897	56·1	·033
Beer	1·028	64·3	·037
Cyder	1·018	63·6	·036
Ether, Acetic	·866	54·1	·031
Ether, Muriatic	·73	45·6	·026
Ether, Sulphuric	·74	46·3	·027
Milk	1·032	64·5	·037
Oil of Aniseed	·987	61·6	·035
Oil of Carraway Seed	·905	56·6	·033
Oil of Cinnamon	1·044	65·3	·038
Oil of Lavender	·894	55·9	·033
Oil of Linseed	·940	58·8	·034
Oil of Mint	·898	56·1	·033
Oil of Olives	·915	57·2	·033
Oil of Turpentine	·87	54.9	·032
Oil of Whale	·923	57·7	·033
Vinegar	1·010	63·1	·036
Water, Distilled	1·0	62·5	·036
Water, Sea	1·026	64·1	·037
Wine, Champagne	·998	62·4	·036
Wine, Maderia	1·038	64·9	·037
Wine, Port	·997	62·3	·036
RESIN, GUMS, &c.			
Assafœtida	1·328	83·	·048
Ashphaltum	·9	56·	·033
Bees' Wax	·967	60·4	·035
Bone of an Ox	1·656	103·5	·06
Butter	·942	58·9	·034
Camphor	·989	61·8	·035
Copal	1·077	67·3	·039
Fat	·93	58·1	·034
Gamboge	1·222	76·4	·044
Gum Arabic	1·452	90·8	·052
Gum, Ammoniac	1·207	75·4	·043
Gum Lac	1·139	71·2	·041
Gunpowder, Shaken	·932	58·3	·034
Gunpowder, Solid	1·745	109·1	·062
Gutta Percha	·98	61·	·035
Honey	1·45	90·6	·052
Indigo	·769	48·1	·022
India Rubber	·934	58·4	·034
Ivory, Dry	1·825	114·1	·066
Lard	·948	59·3	·034
Madder Root	·765	47·8	·022
Opium	1·336	83·5	·048
Sandarac	1·092	63·3	·036
Spermaceti	·943	58·9	·034
Sugar, White	1·606	100·4	·058
Tallow	·942	58·9	·034
Tar	1·015	63·4	·036
Wax, Shoemakers'	·897	56·1	·033

APPROXIMATE EQUIVALENT OF METRIC AND BRITISH MEASURES AND WEIGHTS, &c.

1 Millimetre	...	=	·039	(about 1/25) inch.
1 Inch	...	=	2·54	(about 2½) centimetres.
1 Metre	...	=	3 ft. 3⅜	inches (about 1 1/11 yards).
1 Kilometre	...	=	·6214	(about ⅝) mile.
1 Mile	...	=	1·609	(about 1⅗) kilometre.
1 Kilometre	...	=	·54	knot (nœud or nautical mile).
1 Knot	...	=	1·852	kilometres.
1 Square centimetre		=	·155	square inch.
1 Square inch	...		6·451	(about 6½) square centimetres.
1 Square metre	...	=	1·196	(about 1⅕) sq. yards, or 10¾ sq. feet.
1 Square yard	...		·836	(about 6/7) square metre.
1 Square foot	...	=	.093	square metre.
1 Acre	...	=	4000	square metres.
1 Hectare	...	=	2·47	(about 2½) acres.
1 Cubic metre	...	=	1·31	(about 1⅓) cubic yards.
1 Cubic yard	...	=	·764	(about ¾) cubic metre.
1 Cubic foot	..	=	·0283	cubic metre.
1 Litre	...	=	·220	gallons (about 1¾) pints.
1 Gallon	...	=	4·54	(about 4½) litres.
1 Cubic foot	...	=	28·3	litres.
1 Gramme	...	=	·035	oz. or about 15½ grains avoirdupois.
1 Gramme	...	=	·065	grains troy.
1 Grains troy	...	=	15·432	grammes.
1 Ounce troy	..	=	31·103	grammes.
1 Pound avoirdupois		=	·454	kilogrammes.
1 Kilogramme	...	=	·020	cwt
1 Kilogramme	...	=	2·205	(about 2⅕) pounds
1 Cwt.	...	=	50·8	(about 51) kilogrammes.
1 Foot pound	...	=	·138	(about 1/7) kilogrammetres.
1 Kilogrammetre	...	=	7·233	(about 7¼) foot pounds.
1 Atmosphere (pressure)		=	14·70	pounds.
1 Pound per square inch (pressure)	...	=	·068	atmosphere.
1 Pound per square inch (pressure)	...	=	·07	kilos per square centimetres.

Other Rules for converting Metric to English Measures and Weights.

Grammes to ounces avoirdupois, multiply by 20 and divide by 567.
Kilogrammes to pounds, multiply by 1,000 and divide by 454.
Litres to gallons, multiply by 22 and divide by 100.
Litres to pints, multiply by 88 and divide by 50.
Millimetres to inches, multiply by 10 and divide by 254.
Metres to yards, multiply by 70 and divide by 64.

METRIC MEASURES AND WEIGHTS.

THE METRIC SYSTEM now so widely adopted is based on:

The metre for linear, superficial and solid measures.
The kilogramme for measures of weight; and
The litre for measures of capacity;
from which all other units are derived.

THE METRE is sub-divided into 1000 millimetres, or 100 centimetres (each of 10mm.), or 10 decimetres (each of 10 cm.)

THE KILOGRAMME = 1000 grammes, or 100 decagrammes (each of 10g.), or 10 hectogrammes (each of 10dkg.)

THE LITRE = 100 centilitres, or 10 decilitres (each of 10cl.)

The multiples of these, with British equivalents will be found in the following tables.

TABLES OF CONVERSIONS.—These afford facilities sufficient for most calculations, if it be borne in mind that any unit is converted into any other unit by merely altering the position of the decimal point.

Example.—We find that four inches = 101·6 millimetres or 10·16 centimetres; or we have 40 inches = 1016 millimetres, or 101·6 centimetres, or 10·16 decimetres, or 1·016 metres.

Converting feet into metres, say 68 feet: We have 60 feet = 18·287 metres, plus 8 feet = 2·438 metres, the total being 20·725 metres, and so on for any other measure, weight or capacity expressed in decimals.

EQUIVALENTS IN BRITISH AND METRICAL MEASURES, WEIGHTS, ETC.

Approximate equivalents will be found at pages 276 and 298.

INCHES = MILLIMETRES.

Inches	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
,, Decimal	·0625	·125	·1875	·250	·3125	·375	·4375	·500
Mm.	1·587	3·175	4·762	6·350	7·237	9·525	11·112	12·700
Inches	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	2	3	4
,, Decimal	·5625	·625	·750	·875	...	...	...	...
Mm.	14·287	15·875	19·050	22·225	25·399	50·799	76·199	101·60
Inches	5	6	7	8	9	10	11	12
Mm.	127·00	152·40	177·80	203·20	228·60	254·00	279·39	304·79

MILLIMETRES = INCHES.

Millimetres ..	1	2	3	4	5	6	7	8	9	10
Inches ...	·039	·079	·118	·157	·197	·236	·276	·315	·354	·394

INCHES = CENTIMETRES.

Inches ...	1	2	3	4	5	6	7	8	9	10
Centimetres...	2·54	5·08	7·62	10·16	12·70	15·24	17·78	20·32	22·86	25·40

CENTIMETRES = INCHES.

Centimetres...	1	2	3	4	5	6	7	8	9	10
Inches ...	·394	·787	1·181	1·575	1·968	2·362	2·756	3·150	3·543	3·940

FEET = METRES.

Feet ...	1	2	3	4	5	6	7	8	9	10
Metres ...	·3048	·6096	·9144	1·219	1·524	1·829	2·134	2·438	2·743	3·048

METRES = FEET.

Metres .	1	2	3	4	5	6	7	8	9	10
Feet ...	3·281	6·562	9·843	13·123	16·404	19·685	22·966	26·247	29·528	32·809

YARDS = METRES.

Yards ...	1	2	3	4	5	6	7	8	9	10
Metres ...	·9144	1·829	2·743	3·658	4·572	5·486	6·400	7·315	8·229	9·143

METRES = YARDS.

Metres ...	1	2	3	4	5	6	7	8	9	10
Yards ...	1·1094	2·187	3·281	4·375	5·468	6·562	7·655	8·749	9·843	10·936

MILES = KILOMETRES.

Miles ...	1	2	3	4	5	6	7	8	9	10
Kilometres ...	1·609	3·219	4·828	6·437	8·046	9·656	11·265	12·875	14·484	16·093

KILOMETRES = MILES.

Kilometres ...	1	2	3	4	5	6	7	8	9	10
Miles ...	·6214	1·243	1·864	2·486	3·107	3·728	4·350	4·971	5·592	6·214

SQUARE INCHES = SQUARE CENTIMETRES.

Sq. Inches ...	1	2	3	4	5	6	7	8	9	10
Sq. Cm. ...	6·452	12·903	19·354	25·806	32·257	38·709	45·160	51·611	58·062	64·513

SQUARE CENTIMETRES = SQUARE INCHES.

Sq. Cm. ...	1	2	3	4	5	6	7	8	9	10
Sq. Inches ...	·155	·310	·465	·620	·775	·930	1·085	1·240	1·395	1·550

SQUARE YARDS = SQUARE METRES.

Sq. Yards ...	1	2	3	4	5	6	7	8	9	10
Sq. Metres ...	·836	1·672	2·508	3·344	4·180	5·017	5·853	6·689	7·525	8·361

SQUARE METRES = SQUARE YARDS.

Sq. Metres ..	1	2	3	4	5	6	7	8	9	10
Sq. Yards ...	1·196	2·392	3·588	4·784	5·980	7·176	8·372	9·568	10·764	11·960

CUBIC INCHES=CUBIC CENTIMETRES.

Cub. Inch ...	1	2	3	4	5	6	7	8	9	10
Cub. Cm. ...	16·38	32·77	49·16	65·55	81·93	98·32	114·7	131·01	147·48	163·87

CUBIC CENTIMETRES = CUBIC INCHES.

Cub. Cm. ...	1	2	3	4	5	6	7	8	9	10
Cub. Inch ...	·061	·122	·183	·244	·305	·366	·427	·488	·549	·610

CUBIC FEET=CUBIC METRES.

Cub. Feet ..	1	2	3	4	5	6	7	8	9	10
Cub. Metres	·0283	·0566	·0849	·1133	·1416	·1699	·1982	·2265	·2548	·2831

CUBIC METRES=CUBIC FEET.

Cub. Metres	1	2	3	4	5	6	7	8	9	10
Cub. Feet ...	35·3	70·6	105·9	141·3	176·6	211·9	247·2	282·5	317·8	353·1

CUBIC YARDS=CUBIC METRES.

Cub. Yards ...	1	2	3	4	5	6	7	8	9	10
Cub. Metres	·7645	1·529	2·294	3·058	3·823	4·587	5·352	6·116	6·881	7·645

CUBIC METRES=CUBIC YARDS.

Cub. Metres	1	2	3	4	5	6	7	8	9	10
Cub. Yards ...	1·308	2 616	3·924	5·232	6·540	7·848	9·156	10·46	11·77	13·08

GALLONS=LITRES.

Gallons ...	1	2	3	4	5	6	7	8	9	10
Litres ...	4·543	9·087	13·630	18·173	22·717	27·260	31·804	36·347	40·891	45·434

LITRES=GALLONS.

Litres ...	1	2	3	4	5	6	7	8	9	10
Gallons ...	·220	·440	·660	·880	1·100	1·320	1·540	1·760	1·980	2·201

POUNDS=KILOGRAMMES.

Pounds ...	1	2	3	4	5	6	7	8	9	10
Kilo. ...	·453	·907	1·361	1·814	2·268	2·722	3·175	3·629	4·082	4·536

KILOGRAMMES=POUNDS.

Kilos. ...	1	2	3	4	5	6	7	8	9	10
Pounds ...	2.205	4·410	6·614	8·818	11·02	13·23	15·43	17·64	19·84	22·65

KNOTS (NAUTICAL MILES)=KILOMETRES.

Knots ...	1	2	3	4	5	6	7	8	9	10
Kilometres ...	1.852	3·704	5·555	7·407	9·260	11·111	12·963	14·815	16·667	18·519

Kilometres=Knots (Nœuds).

Kilometres ...	1	2	3	4	5	6	7	8	9	10
Knots ...	·54	1·08	1·62	2·16	2·70	3·24	3·78	4·32	4·86	5·4

Acres=Hectares.

Acres ...	1	2	3	4	5	6	7	8	9	10
Hectares ...	·405	·809	1·214	1·619	2·023	2·428	2·833	3·237	3·642	4·047

Hectares=Acres.

Hectares ...	1	2	3	4	5	6	7	8	9	10
Acres ...	2·471	4·942	7·413	9·885	12·356	14·827	17·298	19·769	22·240	24·711

Grains Troy=Grammes.

Grains Troy...	1	2	3	4	5	6	7	8	9	10
Grammes ...	·065	·130	·194	·259	·324	·389	·454	·518	·583	·648

Grammes=Grains Troy.

Grammes ...	1	2	3	4	5	6	7	8	9	10
Grains Troy	15·432	30·865	46·297	61·729	77·162	92·594	108·026	123·459	138·891	154·324

Foot Pounds=Kilogramme-Metres.

Foot pounds	1	2	3	4	5	6	7	8	9	10
Kilo. metres	·138	·277	·415	·553	·691	·830	·968	1·106	1·244	1·383

Kilogramme-Metres=Foot Pounds.

Kilo. metres	1	2	3	4	5	6	7	8	9	10
Foot pounds	7·233	14·466	21·699	28·933	36·166	43·399	50·632	57·865	65·098	72·331

Lbs. per Square Inch=Kilogrammes per Square Centimetre.

Lbs. per square inch	1	2	3	4	5
Kilogrammes per CM.^{2} ...	14·223	28·446	42·669	56·891	71·114
Lbs. per square inch	6	7	8	9	10
Kilogrammes per CM.^{2} ...	85·337	99·560	113·783	128·005	142·228

Kilogrammes per Square Centimetre=Lbs. per Square Inch.

Kg. per Cm.^{2}	1	2	3	4	5	6	7	8	9	10
Lbs. per sq. in.	·071	·141	·211	·281	·352	·422	·492	·563	·633	·703

Lbs. per Square Inch=Atmospheres.

Lbs. per sq. in.	1	2	3	4	5	6	7	8	9	10
Atmospheres	·068	·136	·204	·272	·340	·408	·476	·544	·612	·680

Atmospheres=Lbs. per Square Inch.

Atmospheres	1	2	3	4	5
Lbs. per square inch	14·706	29·412	44·118	58·824	73·530
Atmospheres	6	7	8	9	10
Lbs. per square inch	88·236	102·942	117·648	132·354	147·060

Lbs. per Yard=Kilogrammes per Metre.

Lbs. per Yard	1	2	3	4	5	6	7	8	9	10
Kg. per Metre	·496	·992	1·488	1·984	2·480	2·976	3·472	3·969	4·465	4·960

Kilogrammes per Metre=Lbs. per Yard.

Kg. per Metre	1	2	3	4	5	6	7	8	9	10
Lbs. per Yard	2·016	4·032	6·048	8·063	10·079	12·095	14·111	16·127	18·143	20·159

Shillings=Francs (approximately).

Shillings ...	1	2	3	4	5	6	7	8	9	10
Francs ..	1·261	2·522	3·784	5·045	6·306	7·567	8·828	10·089	11·351	12·612

Francs=Shillings (approximately).

Francs ...	1	2	3	4	5	6	7	8	9	10
Shillings ..	·793	1·586	2·379	3·172	3·965	4·757	5·550	6·343	7·136	7·929

Francs per Metre=Shillings per Yard (Lineal).

Fcs. per metre	1	2	3	4	5	6	7	8	9	10
Shills. per yard	·725	1·450	2·175	2·900	3·625	4·350	5·075	5·800	6·525	7·250

Shillings per Yard=Francs per Metre (Lineal).

Shills. per yard	1	2	3	4	5	6	7	8	9	10
Fcs. per metre	1·379	2·758	4·138	5·517	6·896	8·275	9·655	11·034	12·413	13·792

Francs per Square Metre=Shillings per Square Yard.

Fcs. sq. metre	1	2	3	4	5	6	7	8	9	10
Shills. p.sq.yd.	·663	1·326	1·989	2·652	3·315	3·978	4·641	5·304	5·967	6·630

Shillings per Square Yard=Francs per Square Metre.

Shills. p.sq.yd.	1	2	3	4	5	6	7	8	9	10
Fcs. sq. metre	1·508	3·017	4·525	6·033	7·542	9·050	10·558	12·067	13·575	15·084

Francs per Cubic Metre=Shillings per Cubic Foot.

Fcs. per stere	1	2	3	4	5	6	7	8	9	10
Shills. per c. ft.	·023	·045	·067	·090	·112	·135	·157	·180	·202	·225

SHILLINGS PER CUBIC FOOT=FRANCS PER STERE (CUBIC METRE).

Shills. per c. ft.	1	2	3	4	5	6	7	8	9	10
Fcs. per stere	44·54	89·08	133·61	178·15	222·69	267·23	311·77	356·31	400·84	445·38

FRANCS PER STERE (CUBIC M.)=SHILLINGS PER CUBIC YARD.

Fr. per Stere	1	2	3	4	5	6	7	8	9	10
Shill. per c. yd.	·606	1·212	1·819	2·425	3·031	3·637	4·244	4·850	5·456	6·062

SHILLINGS PER CUBIC YARD=FRANCS PER STERE.

Shill. per c. yd.	1	2	3	4	5	6	7	8	9	10
Fr. per Stere	1·650	3·299	4·949	6·598	8·248	9·897	11·547	13·197	14·846	16·496

FRANCS PER KILOGRAMME=SHILLINGS PER LB. (AV.)

Fr. per Kilo.	1	2	3	4	5	6	7	8	9	10
Shill. per lb.	·360	·719	1·079	1·439	1·798	2·158	2·518	2·877	3·237	3·597

SHILLINGS PER LB.=FRANCS PER KILOGRAMME.

Shill. per lb.	1	2	3	4	5	6	7	8	9	10
Fr. per Kilo.	2·780	5·561	8·341	11·122	13·902	16·683	19·463	22·243	25·024	27·804

KILOWATTS (B.T. UNIT)=HORSE POWER (ENGLISH).

Kilowatts ...	1	2	3	4	5	6	7	8	9	10
H.P.	1·340	2·681	4·021	5·361	6·702	8·042	9·382	10·723	12·063	13·404

HORSE POWER (ENGLISH)=KILOWATTS (B.T.U.)

H.P. ...	1	2	3	4	5	6	7	8	9	10
Kilowatts ...	·746	1·492	2·238	2·984	3·730	4·476	5·222	5·969	6·715	7·461

TABLES OF METRIC MEASURES & WEIGHTS AND BRITISH EQUIVALENTS.

LINEAL MEASURE.

METRIC.	CONTRACTION	METRES.	INCHES.	FEET.	YARDS.	MILES.
Millimetre ...	Mm.	·001	·039	·003	·001	—
Centimetre ...	Cm.	·010	·394	·033	·011	—
Decimetre ...	Dm.	·100	3·937	·328	·109	—
Metre ...	M.	1·000	39·371	3·281	1·094	—
Decametre ...	—	10·000	—	32·809	10·936	·006
Hectometre ...	—	100·000	—	328·090	109·363	·062
Kilometre ...	Km.	1,000·000	—	3,280·900	1,093·630	·621
Myriametre ..	—	10,000·000	—	—	—	6·214

SQUARE MEASURE.

METRIC.	CONTRACTION	SQUARE METRES.	SQUARE INCHES.	SQUARE FEET.	SQUARE YARDS.	ACRES.
Milliare ...	Mm.[2]	·1	155·	1·076	·119	—
Centiare ...	Cm.[2]	1·000	1550·	10·764	1·196	—
Deciare ...	Dm.[2]	10·000	15501·	107·640	11·960	·002
Are ...	A	100·000	—	1076·400	119·600	·025
Decare ...	—	1,000·000	—	—	1,1196·000	·247
Hectare ...	Ha.	10,000·000	—	—	11,960·000	2·471

SOLID MEASURE.

METRIC.	CONTRACTION	CUB. METRE.	CUB. INCHES.	CUB. FEET.	CUB. YARDS.
Millistere ...	Mm.[3]	·001	61·028	—	—
Centistere ...	Cm.[3]	·010	610·280	·353	—
Decistere ...	Dm.[3]	·100	6,102·800	3·532	·131
Stere or Cubic Metre	M.[3]	1·000	61,028·000	35·317	1·308
Decastere ...	—	10·000	—	—	13·080
Hectostere ..	—	100·000	—	—	130·802

WEIGHTS.

METRIC.	CONTRACTION	GRAMMES.	AVOIRDUPOIS OUNCES.	AVOIRDUPOIS LBS.	CWTS.	TONS.	GRAINS TROY
Milligramme	Mg.	·001	—	—	—	—	·015
Centigramme	Cg.	·010	—	—	—	—	·154
Decigramme	Dg.	·100	—	—	—	—	1·543
Gramme	G.	1·000	·035	·002	—	—	15·432
Decagramme	Dkg.	10·000	·352	·022	—	—	
Hectogramme	—	100·000	3·527	·221	—	—	OZ. TROY
Kilogramme	Kg.	1,000 000	35·274	2 205	·019	·001	32·150
Myriagramme	—	10,000·000	—	22·046	·197	010	—
Quintal	Q.	100,000 000	—	220·462	1·968	·098	—
Millier or Bar	—	1,000,000·000	—	2204·620	19·684	·984	—

DRY AND FLUID MEASURES.

METRIC.	CONTRACTION	LITRES.	INCHES.	FEET.	GALLONS.	BUSHELS.
Millilitre ...	Ml.	·001	·061	—	—	—
Centilitre ..	Cl.	·010	·610	—	·002	—
Decilitre ...	Dl.	·100	6·100	—	·022	·003
Litre ...	L	1·000	61·020	·035	·220	·028
Decalitre ...	Dkl.	10·000	610·280	·353	2·200	·276
Hectolitre ...	Hl.	100·000	...	3·531	22·009	2·751
Kilolitre ...	—	1,000,000	...	35·317	220 096	27·512
Myrialitre ...	—	10,000,000	...	353·170	2200·967	275·121

BRITISH STANDARD MEASURES AND WEIGHTS AND METRICAL EQUIVALENTS.

LINEAL MEASURES.

BRITISH STANDARD.	METRICAL EQUIVALENT.
1 inch	25·400 millimetres
1 Foot (12 inches)	·305 metres
1 Yard (3 feet)	·914 ,,
1 Fathom (6 feet)	1·829 ,,
1 Pole or Perch (5½ yards)	5·029 ,,
1 Chain (22 yards)	20·116 ,,
1 Furlong (220 yards)	201·64 ,,
1 Mile (8 furlongs)	1·6093 kilometers
1 Nautical mile (knot 6076 feet)	1·852 ,,

SQUARE MEASURES.

BRITISH STANDARD.	METRICAL EQUIVALENT.
1 Square Inch	6·451 square centimetres
1 Square Foot (144 square inches)	9·290 square decimetres
1 Square Yard (9 square feet)	·836 square metres
1 Perch (20¼ square yards)	25·293 ,,
1 Rood (40 perches)	10·117 ares
1 Acre (4840 square yards)	·405 hectare
1 Square Mile (640 acres)	258·9894 ,,

SOLID MEASURES.

BRITISH STANDARD.	METRICAL EQUIVALENT.
1 Cubic Inch	16·387 cubic centimetres
1 Cubic Foot (1728 cubic inches)	·0283 cubic metres
1 Cubic Yard (27 cubic feet)	·7646 ,,

MEASURES OF CAPACITY (COMMERCIAL.)

BRITISH STANDARD.	METRICAL EQUIVALENT.
1 Gill	1·42 decilites
1 Pint (4 gills)	·568 litre
1 Quart (2 pints)	1·136 ,,
1 Gallon (4 quarts)...	4·543 ,,
1 Peck (2 gallons)	9·087 ,,
1 Bushel (4 pecks)	3·635 decalitres
1 Quarter (8 bushel)	2·908 hectolitres

MEASURES OF WEIGHT (AVOIRDUPOIS).

BRITISH STANDARD.	METRICAL EQUIVALENT.
1 Dram	1·772 grammes
1 Ounce (16 drams)	28·350 ,,
1 Pound (lb.—16 oz.)	·454 kilogrammes
1 Stone (14 lbs.)	6·350 ,,
1 Quarter (28 lbs.)	12·70 ,,
1 Hundredweight (cwt.—112 lbs.)	·508 quintal
1 Ton (20 cwt.)	1016 kilogrammes

APOTHECARIES MEASURES.

BRITISH STANDARD.	METRICAL EQUIVALENT.
1 Minim	·059 millilitres
1 Scruple (fluid)	1·184 ,,
1 Drachm ,, (60 minims)	3·552 "
1 Ounce ,, (8 drachms)	2·841 centilitres
1 Pint	·568 litres
1 Gallon (8 pints or 160 fluid oz.	4·546 ,,

TROY WEIGHT.

BRITISH STANDARD.	METRICAL EQUIVALENT.
1 Grain	·0648 gramme
1 Pennyweight (dwt.—24 grains)	1·555 ,,
1 Ounce troy (20 dwt.)	31·104 ,,

APOTHECARIES WEIGHT.

BRITISH STANDARD.	METRICAL EQUIVALENT.
1 Grain	·0648 gramme
1 Scruple (20 grains)	1·296 ,,
1 Drachm (3 scruples)	3·888 ,,
1 Ounce (8 drachms)	31·104 ,,

JAPANESE MEASURES AND WEIGHTS WITH BRITISH AND METRIC EQUIVALENTS.

LINEAL MEASURES.

JAPANESE.	BRITISH.	METRIC.
Shaku	11·931 inches.	30·303 c/m.
Ken = 6 Shaku	5·965 feet.	1·818 metres.
Chō = 60 Ken	119·305 yards.	109·080 ,,
Ri = 36 Chō	2·4403 miles.	3·927 k/m.

SUPERFICIAL (SQUARE) MEASURES.

JAPANESE.	BRITISH.	METRIC.
Square Shaku	5·9310 sq. feet.	·5509 sq. m.
Tsubo (or bu) = 6 square Shaku	3·9540 sq. yards	3·305 ,,
Se = 30 Tsubo	3·921 sq. perches.	·9918 decametres.
Tan = 300 Tsubo	39·21 ,, ,,	9·917 ,,
Chō = 3000 Tsubo	2·450 acres.	99·178 ,,

MEASURES OF CAPACITY.

JAPANESE.	BRITISH.	METRIC.
Sho	3·176 pints.	1·8039 litres.
To = 10 Sho	3·968 gallons.	18·039 ,,
Koku = 100 Sho	39·685 galls. or 6·370 cub. ft.	180·390 ,,

MEASURES OF WEIGHT.

JAPANESE.	BRITISH.	METRIC.
Momme	2·1235 drachms (av.) or 57·871 grains (troy)	3·750 gramme.
Kan = 1000 Momme	8·292 lbs. (avoir).	3·750 kg.
Kin = 160 Momme	1·326 lbs.	600 gramme.

RUSSIAN MEASURES AND WEIGHTS WITH BRITISH AND METRIC EQUIVALENTS.

LINEAL MEASURES.

RUSSIAN.	BRITISH.	METRIC.
Arshine	·778 yard (28 inches)	71·12 centimetres
Sagene (3 arshines)	7 feet	2·134 metres
Verst (500 sagenes)	·663 miles	1·067 kilometres

British inches and feet are generally used by engineers for lineal, square and cubic measures.

LIQUID MEASURES.

RUSSIAN.	BRITISH.	METRIC.
Krushka	1·082 quarts	1·024 litres
Vedro (10 krushka)	2·707 gallons	10·246 ,,

DRY MEASURES.

RUSSIAN.	BRITISH.	METRIC.
Tschetverik	5·775 gallons	21·780 litres
Tschetvert (8 Tschetveriks) ...	5·775 bushels	·174 cubic metres

WEIGHTS.

RUSSIAN.	BRITISH.	METRIC.
Zolotnik	·0094 lbs.	·0043 kilogrammes
Funt (96 zolotniks)	·9028 lbs.	·4128 ,,
Pood (40 funts)	36·114 lbs.	16·373 ,,

EQUIVALENTS FOR OTHER COUNTRIES, in weights, measures and coinage (approximately) will be found in the tables at page 292.

ELECTRICAL MEASURES.—The chief units, for practical and commercial purposes, will be found at page 290.

ATMOSPHERIC STANDARDS.

BRITISH STANDARD.—This is used in Great Britain, the Colonies, the United States of America, Russia and a few other countries and is :

One pound per square inch=2·035 inches of mercury column.
One atmosphere=14·7 lbs. per square inch=29·9 inches mercury column.

METRIC STANDARD.—This is used in France, Germany, and the numerous other countries which have adopted the metric system (vide page 294) and is :

One atmosphere=1 kilogramme per square centimetre, or
,, =735 millimetres mercury column, or
,, =14·22 lbs. per square inch, or
,, =28·94 inches of mercury column.

WEIGHT OF AIR.—This varies with the temperature and pressure of the air, the weight of one cubic foot of air at atmospheric pressure being ·0807 lbs. at 32° Fahr. and ·069 lbs. at a temperature of 212°, increasing respectively to ·3551 lbs. and ·2600 lbs. at a pressure of 50 lbs. per square inch, and to ·6295 lbs. and ·4609 lbs. at 100 lbs. per square inch.

APPROXIMATE WEIGHTS AND MEASUREMENTS OF BALES, &c.

Cotton in bales, Indian ...	Average weight	392 lbs.	Meas. 10 cubic feet.
,, ,, Egyptian ...	,, ,,	756 lbs.	,, 20 ,, ,,
,, ,, American ...	,, ,,	504 lbs.	,, 14 to 15 c. ft.
Australian wool in bales, Greasy	,, ,,	385 lbs.	,, 20 cubic feet.
,, ,, ,, Scoured	,, ,,	285 lbs.	,, 18 ,, ,,
Portland cement in cask ...	,, ,,	400 lbs.	,, 5 ,, ,,

WEIGHT OF MEN.—A crowd of men densely packed weigh about 120 lbs. per superficial foot of floor.

WEIGHTS OF ANIMALS.—These are approximately :

Saddle horse 8 cwt. **Cavalry horse** 11 cwt. **Strong cart horse** 14 cwt.

Oxen about 8 cwt. **A large cow** 6½ cwt. **Pig** 1¼ cwt. **Sheep** ¾ cwt.

DECIMAL APPROXIMATIONS OF MEASURES AND WEIGHTS.

Lineal feet	multiplied by	·00019	=	miles.	
,, yards	,,	·000568	=	,,	
Square inches	,,	·007	=	square feet.	
,, yards	,,	·0002067	=	acres.	
Circular inches	,,	·00546	=	square feet.	
Cylindrical inches	,,	·0004546	=	cubic feet.	
,, feet	,,	·02909	=	cubic yards.	
Cubic inches	,,	·00058	=	cubic feet.	
,, feet	,,	·03704	=	cubic yards.	
,, ,,	,,	6·232	=	imperial gallons.	
,, inches	,,	·003607	=	,,	,,
Cylindrical feet	,,	4·895	=	,,	,,
,, inches	,,	·002832	=	,,	,,
Cubic inches	,,	·263	=	lbs. av.s	of cast iron.
,, ,,	,,	·281	=	,,	wrought iron.
,, ,,	,,	·283	=	,,	steel.
,, ,,	,,	·3225	=	,,	copper.
,, ,,	,,	·3037	=	,,	brass.
,, ,,	,,	·26	=	,,	zinc.
,, ,,	,,	·4103	=	,,	lead.
,, ,,	,,	·2636	=	,,	tin.
,, ,,	,,	·4908	=	,,	mercury.
Cylindrical inches	,,	·2065	=	,,	cast iron.
,, ,,	,,	·2168	=	,,	wrought iron.
,, ,,	,,	·2223	=	,,	steel.
,, ,,	,,	·2533	=	,,	copper.
,, ,,	,,	·2385	=	,,	brass.
,, ,,	,,	·2042	=	,,	zinc.
,, ,,	,,	·3223	=	,,	lead.
,, ,,	,,	·207		,,	tin.
,, ,,	,,	·3854	=	,,	mercury.
Avoirdupois lbs.	,,	·009	=	cwts.	
,, ,,	,,	·00045	=	tons.	

TIMBER.—40 cubic feet rough, or 50 cubic feet squared=1 load.
50 cubic feet of planks=1 load.
100 superficial feet=1 square of flooring.
120 deals=100.
Deals are 9 inches wide. Battens 7 inches.
Planks are 2 to 4 inches thick, and 10 or 11 inches wide.

A CORD OF WOOD usually=125 cubic feet and weighs about 2½ tons, but quantity and weight vary in different countries.

WEIGHTS OF SQUARE AND ROUND BAR IRON

In lbs. per Lineal Foot.

BREADTH OR DIAMETER.	SQUARE BARS.	ROUND BARS.	BREADTH OR DIAMETER.	SQUARE BARS.	ROUND BARS.	BREADTH OR DIAMETER.	SQUARE BARS.	ROUND BARS.
Inches.			Inches.			Inches.		
3/16	·117	·209	1 1/8	4·22	3·32	2 7/8	27·61	21·68
1/4	·208	·164	1 1/4	5·25	4·09	3	30·07	23·60
5/16	·326	·256	1 3/8	6·35	4·96	3 1/4	35·28	27·70
3/8	·470	·369	1 1/2	7·51	5·90	3 1/2	40·91	32·13
7/16	640	·502	1 5/8	8·82	6·92	3 3/4	46·97	36·89
1/2	835	·656	1 3/4	10·29	8·03	4	53·44	41·27
9/16	1·057	·831	1 7/8	11·74	9·22	4 1/4	60·32	47·38
5/8	1·305	1·025	2	13·36	10·49	4 1/2	67·63	53·12
11/16	1·579	1·241	2 1/8	15·08	11·84	4 3/4	73·35	59·18
3/4	1·879	1·476	2 1/4	16 91	13·27	5	83·51	65·58
13/16	2·205	1·732	2 3/8	18·84	14·79	5 1/4	92·46	72·30
7/8	2·556	2·011	2 1/2	20·87	16·39	5 1/2	101·03	79·35
15/16	2·936	2·306	2 5/8	23·11	18·07	5 3/4	110·43	86·73
1	3·34	2·62	2 3/4	25·26	19·84	6	120·24	94·43

For weights of bars of larger sizes multiply by 4 the weight of a bar half the size required.

EXAMPLE: A bar 4 1/4 inches diameter weighs 47·38 lbs., which, multiplied by 4, gives 189·52 lbs., the weight per foot of a bar 8 1/2 inches diameter.

For estimating weights of other metals, see bottom of page.

FLAT BAR IRON

Sectional Areas in Inches and Weights in lbs. per Lineal Foot.

THICKNESS INCH.	WIDTH IN INCHES. 1		2		3		4		5		6	
	AREA SQUARE INCH.	WEIGHT LBS.	AREA SQUARE INCH.	WEIGHT LBS.	AREA SQUARE INCH.	WEIGHT LBS.	AREA SQUARE INCH.	WEIGHT LBS.	AREA SQUARE INCH.	WEIGHT LBS.	AREA SQUARE INCH.	WEIGHT LBS.
1/4	·250	·833	·500	1·67	·750	2·50	1·00	3·33	1·25	4·17	1·50	5.00
5/16	·313	1·04	·625	2·08	·938	3·13	1·25	4·17	1·56	5·21	1·88	6·25
3/8	·375	1·25	·750	2·50	1·13	3·75	1·50	5·00	1·88	6·25	2·25	7·50
7/16	·438	1·46	·875	2·92	1·31	4·38	1·75	5·83	2·19	7·29	2·63	8·75
1/2	·500	1·67	1·00	3·33	1·50	5·00	2·00	6·67	2·50	8·33	3·00	10·0
9/16	·563	1·88	1·13	3·75	1·69	5·63	2·25	7·50	2·81	9·38	3·38	11·3
5/8	·625	2·08	1·25	4·17	1·88	6·25	2·50	8·33	3·13	10·4	3·75	12·5
11/16	·688	2·29	1·38	4·58	2·06	6 88	2 75	9·17	3·44	11·5	4·13	13·8
3/4	·750	2·50	1·50	5·00	2·25	7·50	3·00	10·0	3 75	12·5	4·50	15·0
13/16	·813	2·71	1·63	5·42	2·44	8·13	3·25	10·8	4·06	13·5	4·88	16·3
7/8	·875	2·92	1·75	5·83	2·63	8·75	3·50	11·7	4·38	14·6	5·25	17·5
15/16	·938	3·13	1·88	6·25	2·81	9·38	3·75	12·5	4·69	15·6	5·63	18·8
1	1.00	3·33	2·00	6·67	3·00	10.0	4.00	13·3	5·00	17·7	6·00	20·0

STEEL AND OTHER METALS.—To find the weights of bars of other metals of equal section, multiply the tabular weights as follows:

FOR STEEL × 1·02. BRASS × 1·09. COPPER × 1·15.
LEAD × 1.47. CAST IRON × ·93. ZINC × ·92.

WEIGHT OF SHEET IRON, COPPER AND LEAD

per superficial foot, in lbs.

Thickness in inches... ...	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$
Iron in lbs.	2·5	5·	7·	10·	12·5	15·
Brass ,, ...	2·7	5·5	8·2	10·9	13·6	16·3
Copper ,, ...	2·9	5·8	8·7	11·6	14·5	17·4
Lead ,, ...	3·7	7·4	11·1	14·8	18·5	22·2
Thickness in inches... ...	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Iron in lbs.	17·5	20·	25·	30·	35·	40·
Brass ,, ...	19·	21·8	27·1	32·5	37·9	43·3
Copper ,, ...	20·3	23·2	28·9	34·7	40·4	46·2
Lead ,, ...	25·9	29·6	37·	44·4	57·8	49·2

WEIGHT OF ANGLE IRON

in lbs. per lineal foot.

Breadth of sides in inches.	Average Thickness of Sides in inches.						
	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$
1	1·46	1·76	2·03	...	...	...	...
1¼	1·88	2·28	2·66	3·01	...	...	...
1½	2·29	2·80	3·28	3·71	...	...	...
1¾	...	3·32	3·91	4·47	...	...	...
2	...	3·84	4·53	5·20	5·82	...	...
2¼	...	4·37	5·16	5·92	6·67	...	...
2½	...	...	5·78	6·65	7·50	...	...
2¾	...	..	6·41	7·38	8·53	9·26	...
3	...	...	7·03	8·11	9·17	10·1	...
3½	...	...	...	9·57	10·8	12·0	...
4	...	...	...	11·0	12·5	13·9	15·3
4½	...	...	...	12·4	14·1	15·8	17·4
5	...	...	...	...	15·8	17·7	19·5
6	...	...	...	...	19·1	21·4	23·7

For estimating the weight of other metals, see the preceding page.

MEAN TENSILE STRENGTH OF METALS.

In Tons per square inch of section.

Wrought iron bars ...	20 to 22	Copper, sheets	about 13
Wrought iron boiler plate	about 21½	Copper wire, annealed ...	,, 13
Wrought iron boiler plate across grain	19½	Gun-metal castings ...	,, 14
Cast steel, usual section ...	27 to 35	Brass, cast	,, 8
Cast steel, for tools ...	about 50	Brass wire, annealed ...	,, 14
Copper, cast	about 10	Tin	,, 2

WEIGHTS OF BOLTS, BOLT HEADS AND NUTS.—The approximate weights of iron bolts of any length will be obtained by adding the weight of bar iron required (see table page 311), to those given in the following tables.

Bolts of other metals.--The weights of these can be calculated with sufficient accuracy by using the constants given, also at page 311.

WEIGHT OF 100 IRON BOLTS, WITH SQUARE HEADS AND NUTS.

Length under Head to point.	DIAMETER OF BOLTS.								
	inch. $\frac{1}{4}$	inch. $\frac{5}{16}$	inch. $\frac{3}{8}$	inch. $\frac{7}{16}$	inch. $\frac{1}{2}$	inch. $\frac{5}{8}$	inch. $\frac{3}{4}$	inch. $\frac{7}{8}$	inch. 1
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs	lbs.	lbs.	lbs.
1½	4·0	7·0	10·5	15·2	22·5	39·5	63·0	...	...
1¾	4·4	7·5	11·3	16·3	23·8	41·6	66·0	...	...
2	4·8	8·0	12·0	17·4	25·2	43·8	69·0	109·0	163
2¼	5·2	8·5	12·8	18·5	26·5	45·8	72·0	113·3	169
2½	5·5	9·0	13·5	19·6	27·8	48·0	75·0	117·5	174
2¾	5·8	9·5	14·3	20·7	29·1	50·1	78·0	121·8	180
3	6·3	10·0	15·0	21·8	30·5	52·3	81·0	126·0	185
3½	7·0	11·0	16·5	24·0	33·1	56·5	87·0	134·3	196
4	7·8	12·0	18·0	26·2	35·8	60·8	93·1	142·5	207
4½	8·5	13·0	19·5	28·4	38·4	65·0	99·1	151·0	218
5	9·3	14·0	21·0	30·6	41·1	69·3	105·2	159·6	229
5½	10·0	15·0	22·5	32·8	43·7	73·5	111·3	168·0	240
6	10·8	16·0	24.0	35·0	46·4	77·8	117·3	176·6	251
6½			25·5	37·2	49·0	82·0	123·4	185·0	262
7			27·0	39·4	51·7	86·3	129·4	193·7	273
7½			28·5	41·6	54·3	90·5	135·0	202·0	284
8			30·0	43·8	59·6	94·8	141·5	210·7	295
9				46·0	64·9	103·3	153·6	217·8	317
10				48·2	70·2	111·8	165·7	224·8	339
11				50·4	75·5	120·3	177·8	261·9	360
12				52·6	80·8	128·8	189·9	278·9	382
13					86·1	137·3	202·0	296.0	404
14					91·4	145·8	214·1	313·0	426
15					96·7	154·3	226·2	330·1	448
16					102·0	162·8	238·3	347·1	470
17					107·3	171·0	250·4	364·2	492
18					112·6	179·5	262·6	381·2	514
19					117·9	188·0	274·7	398·3	536
20					123·2	206·5	286·8	415·3	558
Per inch additional	1·4	2·1	3·1	4·2	5·5	8·5	12·3	16·7	21·8

WEIGHTS OF NUTS AND BOLT HEADS,

FOR CALCULATING THE WEIGHTS OF LONGER BOLTS.

Diameter of bolt in inches ...		$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	1¼	1½
Weight of hexagon nut and head	lb.	·017	·057	·128	·267	·43	·73	1·10	2·14	3·78
Weight of square nut and head ...	,,	·021	·069	·164	·320	·55	·88	1·31	2·56	4·42

TABLE OF WIRE AND SHEET GAUGES.

NUMBER GAUGE.	ENGLISH IMPERIAL LEGAL STANDARD.	BIRMINGHAM OR STUBBS, OR ENGLISH STANDARD.	BIRMINGHAM FOR SHEETS, NOT IRON OR STEEL.	BIRMINGHAM FOR IRON SHEETS.	LANCASHIRE, ONE OF HOLTZAPFFELS.	WARRINGTON OR RYLANDS.	OLD ENGLISH FOR BRASS, ETC.	NEEDLE WIRE.	MUSIC WIRE IN ENGLAND.	WHITWORTH'S ENGLISH STANDARD.	AMERICAN NEW LEGAL STANDARD.	BROWN & SHARPE AMERICAN STANDARD
000000C0	·500	...	...	...	...	·500	...	...	...	...	·500	...
000000	·464	...	...	...	...	·468+	...	...	...	...	·468+	...
00000	·432	...	..	..	...	·437+	...	...	...	...	·437+	...
0000	·400	.454	...	...	...	·406+	...	...	...	..	·406	·460
000	·372	·425	...	...	...	·375	...	...	...	...	·375	·409+
00	·348	·380	...	...	...	·343+	...	...	...	...	·343+	·364+
0	·324	·340	...	...	...	·326	...	...	...	...	·312+	·324+
1	·300	·300	·c04	·312+	·227	·300	...	·045	...	·001	·281+	·289+
2	·276	·284	·c05	·281+	·219	·274	...	·042	...	·002	·265+	·257+
3	·252	·259	·008	·250	·209	·250	...	·035	...	·003	·250	·229+
4	·232	·238	·010	·234+	·204	·229	...	·032	...	·004	·234+	·204+
5	·212	·220	·012	·218+	·201	·209	..	·028	...	·005	·218+	·181+
6	·192	·203	·013	·203+	·198	·191	...	·025	·018	·006	·203+	·162+
7	·176	·180	·015	·187+	·195	·174	...	·022	·019	·c07	·187+	·144+
8	·160	·165	·016	·171+	·192	·159	...	·020	·020	·008	·171+	·128+
9	·144	·148	·019	·156+	·191	·146	...	·018	·021	·009	·156+	·114+
10	·128	·134	·024	·140+	·190	·133	...	·016	·022	·010	·140+	·101+
11	·116	·120	·029	·125	·189	·117	...	·014	·023	·011	·125	·090+
12	·104	·109	·034	·112+	·185	·100	...	·013	·025	·012	·109+	·080+
13	·092	·095	·036	·100	·180	·090	...	·012	·026+	·013	·093+	·071+
14	·080	·083	·041	·087+	·177	·079	·083	·010	·028	·014	·078+	·064+
15	·072	·072	·047	·075	·175	·069	·072	·009	·030	·015	·080+	·057+
16	·064	·065	·051	·062+	·174	·062+	065	·008	·032	·016	·062+	·050+
17	·056	·058	·057	·056+	·169	·053	058	·007	·033+	·017	·056+	·045+
18	·048	·049	·061	·050	·167	·047	049	·005	·035	·018	·050	·040+
19	·040	·042	·064	·043+	·164	·041	040	·004	·038	·019	·043+	·035+
20	·036	·035	·067	·037+	·160	·036	035	·003	·042	·020	·037+	·031+
21	·032	·032	·072	·034+	·157	·031+	031+	·002	...	...	·034+	·028+
22	·028	·028	·074	·031+	·152	·028	029+	...	...	·022	·031+	·025+
23	·024	·025	·077	·028+	·150	...	027	...	...	...	·028+	·022+
24	·022	·022	·082	·025	·148	...	025	...	...	·024	·025	·020+
25	·020	·020	·095	·023+	·146	...	023	...	...	...	·021+	·017+
26	·018	·018	·103	·021+	·143	...	020+	...	...	·026	·018+	·015+
27	·016+	·016	·113	·020+	·141	...	018+	...	...	...	·017+	·014+
28	·014+	·014	·120	·018+	·138	...	016+	...	...	·028	·015+	·012+
29	·013+	·013	·124	·017+	·134	...	015+	...	...	...	·014+	·011+
30	·012+	·012	·126	·015+	·125	...	013+	...	...	·030	·012+	·010+
31	·011+	·010	·133	·014+	·118	...	012+	...	...	...	·010+	·c08+
32	·010+	·009	·143	·012+	·115	...	011+	..	...	·032	·010+	·007+
33	·010	·008	·145	...	·111	...	010+	...	...	...	·009+	·007+
34	·009+	·007	·148	...	·109	...	009	...	...	·034	·008+	·006+
35	·c08+	·005	·158	...	·107	...	009+	...	.	...	·007+	·005+
36	·007+	·004	·169	...	·105	...	007+	...	...	·036	·007+	·005
37	·006+	...	...	..	·102	...	006+	...	...	...	·006+	·004+
38	·006	...	...	...	·100	...	005+	...	...	·038	·006+	·003+
39	·005+	...	...	..	·098	...	005	...	...	...	...	·002+
40	·004+	.	...	...	·096	...	004+	...	...	·040	...	·c03+
41	·004+	...	...	...	·095	...	...	...	...	...	...	...
42	·004	...	...	...	·c91	..	...	...	...	...	...	...

(Mechanical World).

CIRCUMFERENCES AND AREAS OF CIRCLES.

DIAM.	CIRCUM.	AREA.	DIAM.	CIRCUM.	AREA.
1/8	.3927	.0122	6 1/4	19.635	30.679
1/4	.7854	.0490	1/2	20.420	33.183
3/8	1.1781	.1104	3/4	21.205	35.784
1/2	1.5708	.1963	7 in.	21.991	38.484
5/8	1.9635	.3068	1/4	22.776	41.282
3/4	2.3562	.4417	1/2	23.562	44.178
7/8	2.7489	.6013	3/4	24.347	47.173
1 in.	3.1416	.7854	8 in.	25.132	50.265
1/8	3.5343	.9940	1/4	25.918	53.456
1/4	3.9270	1.2271	1/2	26.703	56.745
3/8	4.3197	1.4848	3/4	27.489	60.132
1/2	4.7124	1.7671	9 in.	28.274	63.617
5/8	5.1051	2.0739	1/4	29.059	67.200
3/4	5.4978	2.4052	1/2	29.845	70.880
7/8	5.8905	2.7611	3/4	30.630	74.662
2 in.	6.2832	3.1416	10 in.	31.415	78.540
1/8	6.6759	3.5465	1/4	32.201	82.516
1/4	7.0686	3.9760	1/2	32.986	86.590
3/8	7.4613	4.4302	3/4	33.772	90.760
1/2	7.8540	4.9087	11 in.	34.557	95.033
5/8	8.2467	5.4119	1/4	35.342	99.402
3/4	8.6394	5.9395	1/2	36.128	103.86
7/8	9.0321	6.4918	3/4	36.913	108.43
3 in.	9.4248	7.0686	12 in.	37.699	113.09
1/8	9.8175	7.6699	1/2	39.269	122.71
1/4	10.210	8.2957	13 in.	40.840	132.73
3/8	10.602	8.9462	1/2	42.411	143.13
1/2	10.995	9.6211	14 in.	45.982	153.93
5/8	11.388	10.320	1/2	45.553	165.13
3/4	11.781	11.044	15 in.	47.123	176.71
7/8	12.173	11.793	1/2	48.694	188.69
4 in.	12.566	12.566	16 in.	50.265	201.06
1/8	12.959	13.364	1/2	51.836	213.92
1/4	13.351	14.186	17 in.	53.407	226.98
3/8	13.744	15.033	1/2	54.977	240.52
1/2	14.137	15.904	18 in.	56.548	254.46
5/8	14.529	16.800	1/2	58.119	268.80
3/4	14.922	17.720	19 in.	59.690	283.52
7/8	15.315	18.665	1/2	61.261	298.64
5 in.	15.708	19.635	20 in.	62.831	314.16
1/8	16.100	20.629	1/2	64.402	330.06
1/4	16.493	21.647	21 in.	65.973	346.36
3/8	16.886	22.690	1/2	67.544	363.05
1/2	17.278	23.758	22 in.	69.115	380.13
5/8	17.671	24.850	1/2	70.685	397.60
3/4	18.064	25.967	23 in.	72.256	415.47
7/8	18.456	26.108	1/2	73.827	433.75
6 in.	18.849	28.274	24 in.	77.398	452.39

CIRCUMFERENCES AND AREAS OF CIRCLES.

DIAM.	CIRCUM.	AREA.	DIAM.	CIRCUM.	AREA.
24½	76.969	471.43	48½	152.36	1847.4
25 in.	78.539	490.87	49 in.	153.93	1885.7
½	80.110	510.70	½	155.50	1924.4
26 in.	81.681	530.93	50 in.	157.07	1963.4
½	83.252	551.54	½	158.65	2002.9
27 in.	84.823	572.55	51 in.	160.22	2042.8
½	86.393	593.95	½	161.79	2083.0
28 in.	87.964	615.75	52 in.	163.36	2123.7
½	89.534	637.94	½	164.93	2164.7
29 in.	91.106	660.52	53 in.	166.50	2206.1
½	92.677	683.49	½	168.07	2248.0
30 in.	94.247	706.86	54 in.	169.64	2290.2
½	95.818	730.61	½	171.21	2332.8
31 in.	97.389	754.76	55 in.	172.78	2375.8
½	98.960	779.31	½	174.35	2419.2
32 in.	100.53	804.24	56 in.	175.92	2463.4
½	102.10	829.57	½	177.50	2507.1
33 in.	103.67	855.30	57 in.	179.07	2551.7
½	105.24	881.41	½	180.64	2596.7
34 in.	106.81	907.92	58 in.	182.21	2042.0
½	108.38	934.82	½	183.78	2687.8
35 in.	109.95	962.11	59 in.	185.35	2733.9
½	111.52	989.80	½	186.92	2780.5
36 in.	113.09	1017.8	60 in.	188.49	2827.4
½	114.66	1046.3	½	190.06	2874.7
37 in.	116.23	1075.2	61 in.	191.63	2922.4
½	117.80	1104.4	½	193.20	2970.5
38 in.	119.38	1134.1	62 in.	194.77	3019.0
½	120.95	1164.1	½	196.34	3067.9
39 in.	122.52	1194.5	63 in.	197.92	3117.2
½	124.09	1225.4	½	199.49	3166.9
40 in.	125.66	1256.6	64 in.	201.06	3216.9
½	127.23	1288.2	½	202.63	3267.4
41 in.	128.80	1320.2	65 in.	204.20	3318.3
½	130.37	1352.6	½	205.77	3369.5
42 in.	131.94	1385.4	66 in.	207.34	3421.1
½	133.51	1418.6	½	208.91	3473.2
43 in.	135.08	1452.2	67 in.	210.48	3525.6
½	136.65	1486.1	½	212.05	3578.4
44 in.	138.23	1520.5	68 in.	213.62	3631.6
½	139.80	1555.2	½	215.19	3685.2
45 in.	141.37	1590.4	69 in.	216.76	3739.2
½	142.94	1625.9	½	218.34	3793.6
46 in.	144.51	1661.9	70 in.	219.91	3848.4
½	146.08	1698.2	½	221.48	3903.6
47 in.	147.65	1734.9	71 in.	223.05	3959.1
½	149.22	1772.0	½	224.62	4015.1
48 in.	150.79	1809.5	72 in.	226.19	4071.5

AREAS AND CIRCUMFERENCES OF CIRCLES ADVANCING BY EIGHTHS OF AN INCH.

The following tables supply the above-named dimensions, in inches, feet, yards or other measure, without calculation, and those on the two following pages are available for diameters exceeding 50, by simply using the "number" as representing "diameter."

The Formulœ at foot of this page will be useful when similar data is required in the sections referred to. For Areas, &c., of higher numbers, see next page.

AREAS.

Diam.	0	1/8	1/4	3/8	1/2	5/8	3/4	7/8
0	.0000	.0122	.0490	.1104	.1963	.3068	.4417	.6013
1	.7854	.9940	1.227	1.484	1.767	2.073	2.405	2.761
2	3.141	3.546	3.976	4.430	4.908	5.411	5.939	6.491
3	7.068	7.669	8.295	8.946	9.621	10.32	11.04	11.79
4	12.76	13.36	14.18	15.03	15.90	16.80	17.72	18.76
5	19.63	20.62	21.64	22.69	23.75	24.85	25.96	27.10
6	28.27	29.46	30.67	31.91	33.18	34.47	35.78	37.12
7	38.48	39.87	41.28	42.71	44.17	45.66	47.17	48.70
8	50.26	51.84	53.45	55.08	56.74	58.42	60.13	61.86
9	63.61	65.39	67.20	69.02	70.88	72.75	74.76	76.58
10	78.54	80.51	82.51	84.54	86.59	88.66	90.76	92.88
11	95.03	97.20	99.40	101.6	103.8	106.1	108.4	110.7
12	113.0	115.4	117.8	120.2	122.7	125.1	127.6	130.1
13	132.7	135.2	137.8	140.5	143.1	145.8	148.4	151.2
14	153.9	156.6	159.4	162.2	165.1	167.9	170.8	173.7
15	176.7	179.6	182.6	185.6	188.6	191.7	194.8	197.9
16	201.0	204.2	207.3	210.5	213.8	217.0	220.3	223.6
17	226.9	230.3	233.7	237.1	340.5	343.9	247.4	250.9
18	254.4	258.0	261.5	265.[illegible]	268.8	272.4	276.1	279.8
19	283.5	287.2	291.0	294.8	298.6	302.4	306.3	310.2
20	314.1	318.1	322.0	326.0	330.0	334.1	338.1	342.2
21	346.3	350.4	354.6	358.8	363.0	367.2	371.5	375.8
22	380.1	384.4	388.8	393.2	397.6	402.0	406.4	410.9
23	415.4	420.0	424.5	429.1	433.7	438.3	443.0	447.6
24	452.3	457.1	461.8	466.6	471.4	476.2	481.1	485.9
25	490.8	495.7	500.7	505.7	510.7	515.7	520.7	525.8
26	530.9	536.0	541.1	546.3	551.5	556.7	562.0	567.2
27	572.5	577.8	583.2	588.5	593.9	599.3	604.8	610.2
28	615.7	621.2	625.7	632.3	637.9	643.5	649.1	654.8
29	660.5	666.2	671.9	677.7	683.4	689.2	695.1	700.9
30	706.8	712.7	718.6	724.6	730.6	736.6	742.6	748.6
31	754.8	760.9	767.0	773.[illegible]	779.3	785.5	791.7	798.0
32	804.2	810.5	816.9	823.2	829.6	836.0	842.4	848.8
33	855.3	861.8	868.3	874.8	881.4	888.0	894.6	901.3
34	907.9	914.6	921.3	928.1	934.8	941.6	948.4	955.3
35	962.1	969.0	975.9	982.8	989.8	996.8	1003	1010
36	1017	1025	1032	1039	1046	1053	1060	1068
37	1075	1082	1089	1097	1104	1111	1119	1126
38	1134	1141	1149	1156	1164	1171	1179	1186
39	1194	1202	1210	1217	1225	1233	1241	1248
40	1256	1264	1272	1280	1288	1296	1304	1312
41	1320	1328	1336	1344	1352	1360	1369	1377
42	1385	1393	1402	1410	1418	1427	1435	1443
43	1452	1460	1469	1477	1486	1494	1503	1511
44	1520	1529	1537	1546	1555	1564	1572	1581
45	1590	1599	1608	1617	1626	1634	1643	1652
46	1661	1671	1680	1689	1698	1707	1716	1725
47	1734	1744	1753	1762	1772	1781	1790	1800
48	1809	1819	1828	1837	1847	1854	1868	1876
49	1885	1895	1905	1914	1924	1934	1943	1953
50	1963	1973	1983	1993	2003	2012	2022	2032

CIRCUMFERENCES.

Diam.	0	1/8	1/4	3/8	1/2	5/8	3/4	7/8	Diam.
0	.0	.3927	.7854	1.178	1.570	1.963	2.356	2.748	0
1	3.141	3.534	3.927	4.319	4.712	5.105	5.497	5.890	1
2	6.283	6.675	7.068	7.461	7.854	8.246	8.639	9.032	2
3	9.424	9.817	10.21	10.60	10.99	11.38	11.78	12.17	3
4	12.56	12.95	13.35	13.74	14.13	14.52	14.92	15.31	4
5	15.70	16.10	16.49	16.88	17.27	17.67	18.06	18.45	5
6	18.88	19.24	19.63	20.02	20.42	20.81	21.20	21.59	6
7	21.99	22.38	22.77	23.16	23.56	23.95	24.34	24.78	7
8	25.13	25.52	25.91	26.31	26.70	27.09	27.48	27.88	8
9	28.27	28.66	29.05	29.45	29.84	30.23	30.63	31.02	9
10	31.41	31.80	32.20	32.59	32.98	33.37	33.77	34.16	10
11	34.55	34.95	35.34	35.73	36.12	36.52	36.91	37.30	11
12	37.69	38.09	38.48	38.87	39.27	39.66	40.05	40.44	12
13	40.84	41.23	41.62	42.01	42.41	42.80	43.19	43.58	13
14	43.98	44.35	44.76	45.16	45.55	45.94	46.33	46.73	14
15	47.12	47.51	47.90	48.30	48.59	49.08	49.48	49.87	15
16	50.26	50.65	51.05	51.44	51.83	52.22	52.62	53.01	16
17	53.40	53.79	54.19	54.58	54.97	55.37	55.76	56.15	17
18	56.54	56.94	57.33	57.72	58.11	58.51	58.90	59.29	18
19	59.69	60.08	60.47	60.86	61.26	61.65	62.04	62.43	19
20	62.83	63.22	63.61	64.01	64.40	64.79	65.18	65.58	20
21	65.97	66.36	66.75	67.15	67.54	67.93	68.32	68.72	21
22	69.11	69.50	69.90	70.29	70.68	71.07	71.47	71.86	22
23	72.25	72.64	73.04	73.43	73.82	74.22	74.61	75.00	23
24	75.39	75.79	76.18	76.57	76.96	77.36	77.75	78.14	24
25	78.54	78.93	79.32	79.71	80.10	80.50	80.89	81.28	25
26	81.68	82.07	82.46	82.85	83.25	83.64	84.03	84.43	26
27	84.82	85.21	85.60	86.00	86.39	86.78	86.17	87.57	27
28	87.96	88.35	88.75	89.14	89.53	89.92	90.32	90.71	28
29	91.10	91.49	91.89	92.28	92.67	93.06	93.46	93.85	29
30	94.24	94.64	95.03	95.42	95.81	96.21	96.60	96.99	30
31	97.39	97.78	98.17	98.56	98.96	99.35	99.74	100.1	31
32	100.5	100.9	101.3	101.7	102.1	102.5	102.9	103.3	32
33	103.7	104.1	104.5	104.9	105.2	105.6	106.0	106.4	33
34	106.8	107.2	107.6	108.0	108.4	108.8	109.2	109.6	34
35	110.0	110.3	110.7	111.1	111.5	111.9	112.3	112.7	35
36	113.1	113.5	113.9	114.3	114.7	115.1	115.5	115.8	36
37	116.2	116.6	117.0	117.4	117.8	118.2	118.6	119.0	37
38	119.4	119.8	120.2	120.6	121.0	121.3	121.7	122.1	38
39	122.5	122.9	123.3	123.7	124.1	124.5	124.9	125.3	39
40	125.7	126.1	126.4	126.8	127.2	127.6	128.0	128.4	40
41	128.8	129.2	129.6	130.0	130.4	130.8	131.2	131.6	41
42	131.9	132.3	132.7	133.1	133.5	133.9	134.3	134.7	42
43	135.1	135.5	135.9	136.3	136.7	137.1	137.4	137.8	43
44	138.2	138.6	139.0	139.4	139.8	140.2	140.6	141.0	44
45	141.4	141.8	142.2	142.6	142.9	143.3	143.7	144.1	45
46	144.5	144.9	145.3	145.7	146.1	146.5	146.9	147.3	46
47	147.7	148.0	148.4	148.8	149.2	149.6	150.0	150.4	47
48	150.8	151.2	151.6	152.0	152.4	152.8	153.2	153.5	48
49	153.9	154.3	154.7	155.1	155.5	165.9	156.3	156.7	49
50	157.1	157.5	157.9	158.3	158.7	159.0	159.4	159.8	50

D = Diameter. $D = \frac{C}{3.14159}$ or $\sqrt{A \div .7854}$ or $C \times .31831$.

A = Area. $A = D^2 \times .7854$ or $(C \div 3.5446)^2$.

C = Circumference. $C = D \times 3.14159$ or $3.5446 \sqrt{A}$.

S = Contents of Sphere. $S = D^3 \times .5236$.

B = Contents of Cylinder. $B = A \times$ length. (A being the area of one end.)

TABLE OF DIAMETERS, AREAS, AND CIRCUMFERENCES, OF CIRCLES AND OF SQUARES, CUBES, SQUARE ROOTS AND CUBE ROOTS.

Number.	Circumference.	Area.	Square.	Cube.	Square Root.	Cube Root.	Number.	Circumference.	Area.	Square.	Cube.	Square Root.	Cube Root.
1	3·14	0·79	1	1	1·000	1·000	61	191·64	2922·47	3721	226981	7·810	3·936
2	6·28	3·14	4	8	1·414	1·260	62	194·78	3019·07	3844	238328	7·874	3·957
3	9·42	7·07	9	27	1·732	1·442	63	197·92	3117·25	3969	250047	7·937	3·979
4	12·57	12·57	16	64	2·000	1·587	64	201·06	3216·99	4096	262144	8·000	4·000
5	15·71	19·63	25	125	2·236	1·710	65	204·20	3318·31	4225	274625	8·062	4·020
6	18·85	28·27	36	216	2·450	1·817	66	207·35	3421·19	4356	287496	8·124	4·041
7	21·99	38·48	49	343	2·646	1·913	67	210·49	3525·65	4489	300763	8·185	4·061
8	25·13	50·27	64	512	2·828	2·000	68	213·63	3631·08	4624	314432	8·246	4·081
9	28·27	63·62	81	729	3·000	2·080	69	216·77	3739·28	4761	328509	8·306	4·101
10	31·42	78·54	100	1000	3·162	2·154	70	219·91	3848·45	4900	343000	8·367	4·121
11	34·56	95·03	121	1331	3·317	2·224	71	223·05	3959·19	5041	357911	8·426	4·140
12	37·70	113·10	144	1728	3·464	2·289	72	226·19	4071·50	5184	373248	8·485	4·160
13	40·84	132·73	169	2197	3·605	2·351	73	229·34	4185·39	5329	389017	8·544	4·179
14	43·98	153·94	196	2744	3·741	2·410	74	232·48	4300·84	5476	405224	8·602	4·198
15	47·12	176·72	225	3375	3·872	2·466	75	235·62	4417·86	5625	421875	8·660	4·217
16	50·27	201·06	256	4096	4·000	2·519	76	238·76	4536·46	5776	438976	8·717	4·235
17	53·41	226·98	289	4913	4·123	2·571	77	241·90	4656·63	5929	456533	8·775	4·254
18	56·55	254·47	324	5832	4·242	2·620	78	245·04	4778·36	6084	474552	8·831	4·272
19	59·69	283·53	361	6859	4·358	2·668	79	248·19	4901·67	6241	493039	8·888	4·290
20	62·83	314·15	400	8000	4·472	2·714	80	251·33	5026·55	6400	512000	8·944	4·309
21	65·97	346·36	441	9261	4·582	2·758	81	254·47	5153·00	6561	531441	9·000	4·326
22	69·12	380·13	484	10648	4·690	2·802	82	257·61	5281·02	6724	551368	9·055	4·344
23	72·26	415·48	529	12167	4·795	2·843	83	260·75	5410·61	6889	571787	9·110	4·362
24	75·40	452·39	576	13824	4·898	2·884	84	263·89	5541·77	7056	592704	9·165	4·379
25	78·54	490·87	625	15625	5·000	2·924	85	267·04	5674·50	7225	614125	9·219	4·396
26	81·68	530·93	676	17576	5·099	2·962	86	270·18	5808·80	7396	636056	9·273	4·414
27	84·82	572·56	729	19683	5·196	3·000	87	273·32	5944·69	7569	658503	9·327	4·431
28	87·96	615·75	784	21952	5·291	3·036	88	276·46	6082·12	7744	681472	9·380	4·447
29	91·11	660·52	841	24389	5·385	3·072	89	279·60	6221·14	7921	704969	9·433	4·461
30	94·25	706·86	900	27000	5·477	3·107	90	282·74	6361·72	8100	729000	9·487	4·481
31	97·39	754·77	961	29791	5·567	3·141	91	285·89	6503·88	8281	753571	9·539	4·497
32	100·53	804·25	1024	32768	5·657	3·174	92	289·03	6647·61	8464	778688	9·591	4·514
33	103·67	855·30	1089	35937	5·744	3·207	93	292·17	6792·91	8649	804357	9·643	4·530
34	106·82	907·92	1156	39304	5·830	3·239	94	295·31	6939·78	8836	830584	9·695	4·546
35	109·96	962·11	1225	42875	5·916	3·271	95	298·45	7088·22	9025	857375	9·746	4·562
36	113·10	1017·88	1296	46656	6·000	3·301	96	301·59	7238·23	9216	884736	9·797	4·578
37	116·24	1075·21	1369	50653	6·082	3·332	97	304·73	7389·81	9409	912673	9·848	4·594
38	119·38	1134·11	1444	54872	6·164	3·361	98	307·87	7542·96	9604	941192	9·899	4·610
39	122·52	1194·59	1521	59319	6·244	3·391	99	311·02	7697·69	9801	970299	9·949	4·626
40	125·66	1256·64	1600	64000	6·324	3·419	100	314·16	7853·98	10000	1000000	10·000	4·642
41	128·81	1320·25	1681	68921	6·403	3·448	101	317·30	8011·85	10201	1030301	10·049	4·657
42	131·95	1385·44	1764	74088	6·480	3·476	102	320·44	8171·28	10404	1061208	10.099	4·672
43	135·09	1452·20	1849	79507	6·557	3·503	103	323·58	8332·29	10609	1092727	10·148	4·687
44	138·23	1520·53	1936	85184	6·633	3.530	104	326·73	8494·87	10816	1124864	10·198	4·702
45	141·37	1590·43	2025	91125	6·708	3·556	105	329·87	8659·01	11025	1157625	10·246	4·717
46	144·51	1661·90	2116	97336	6·782	3·583	106	333 01	8824·73	11236	1191016	10·295	4·732
47	147·66	1734·94	2209	103823	6·856	3·609	107	336·15	8992·02	11449	1225043	10·344	4·747
48	150·80	1809·56	2304	110592	6·928	3·634	108	339·29	9160·88	11664	1259712	10·392	4·762
49	153·94	1885·74	2401	117649	7·000	3.659	109	342·43	9331·32	11881	1295029	10·440	4·776
50	157·08	1963·50	2500	125000	7·071	3·684	110	345·58	9503·32	12100	1331000	10·488	4·791
51	160·22	2042·82	2601	132651	7·141	3·708	111	348·72	9676·89	12321	1367631	10·536	4·806
52	163·36	2123·72	2704	140608	7·211	3·732	112	351·86	9852·03	12544	1404928	10·583	4·820
53	166·50	2206·18	2809	148877	7·280	3·756	113	355·00	10028·75	12769	1442897	10·630	4·834
54	169·65	2290·22	2916	157464	7·348	3·779	114	358·14	10207·03	12996	1481544	10·677	4·848
55	172·79	2375·83	3025	166375	7·416	3·802	115	361·28	10386·89	13225	1520875	10·723	4·862
56	175·93	2463·01	3136	175616	7·483	3·825	116	364·42	10568·32	13456	1560896	10·770	4·876
57	179·07	2551·76	3249	185193	7·549	3·848	117	367·56	10751·32	13689	1601613	10 816	4·890
58	182·21	2642·08	3364	195112	7·615	3·870	118	370·70	10935·88	13924	1643032	10·862	4·904
59	185·35	2733·97	3481	205379	7·681	3·892	119	373·85	11122·02	14161	1685159	10·908	4·918
60	188·50	2827·43	3600	216000	7·746	3·915	120	376·99	11309·73	14400	1728000	10·954	4·932

TABLE OF DIAMETERS, AREAS, &c.—*continued.*

Number.	Circumference.	Area.	Square.	Cube.	Square Root.	Cube Root.
121	380.13	11499·01	14641	1771561	11·000	4·946
122	383·27	11689·87	14884	1815848	11·045	4·959
123	386·41	11882·29	15129	1860867	11·090	4·973
124	389·56	12076·28	15376	1906624	11·135	4·986
125	392·70	12271·85	15625	1953125	11·180	5·000
126	395·84	12468·98	15876	2600376	11·224	5·013
127	398·98	12667·69	16129	2048383	11·269	5·026
128	402·12	12867·96	16384	2097152	11·314	5·039
129	405·27	13069·81	16641	2146689	11·357	5·052
130	408·41	13273·23	16900	2197000	11·401	5·065
131	411·55	13478·22	17161	2248091	11·445	5·078
132	414·69	13684·78	17424	2299968	11·489	5·091
133	417·83	13892·91	17689	2352637	11·532	5·104
134	420·97	14102·61	17956	2406104	11·575	5·117
135	424·12	14313·88	18225	2460375	11·618	5·129
136	427·26	14526·72	18496	2515456	11·661	5·142
137	430·40	14741·14	18769	2571353	11·704	5·155
138	433·54	14957·12	19044	2620872	11·747	5·167
139	436·68	15174·68	19321	2685619	11·789	5·180
140	439·82	15393·80	19600	2744000	11·832	5·192
141	442·96	15614·50	19881	2803221	11·874	5·204
142	446·11	15836·77	20164	2863288	11·916	5·217
143	449·25	16060·61	20449	2924207	11·958	5·229
144	452·39	16286·02	20736	2985984	12·000	5·241
145	455·53	16513·00	21025	3048625	12·041	5·253
146	458·67	16741·55	21316	3112136	12·083	5·265
147	461·81	16971·67	21609	3176523	12·124	5·277
148	464·96	17203·36	21904	3241792	12·165	5·289
149	468·10	17436·62	22201	3307949	12·206	5·301
150	471·24	17671·46	22500	3375000	12·247	5·313
151	474·38	17907·86	22801	3442951	12·288	5·325
152	477·52	18145·84	23104	3511808	12·328	5·336
153	480·66	18385·39	23409	3581577	12·369	5·348
154	483·81	18626·50	23716	3652264	12·409	5·360
155	486·95	18869·19	24025	3723875	12·449	5·371
156	490·09	19113·45	24336	3796416	12·489	5·383
157	493·23	19359·28	24649	3869893	12·529	5·394
158	496·37	19606·68	24964	3944312	12·569	5·406
159	499·51	19855·65	25281	4019679	12·609	5·417
160	502·65	20106·19	25600	4096000	12·649	5·428
161	505·80	20358·31	25921	4173281	12·688	5·440
162	508·94	20611·99	26244	4251528	12·727	5·451
163	512·08	20867·19	26569	4330747	12·767	5·462
164	515·22	21124·07	26896	4410944	12·806	5·473
165	518·36	21382·47	27225	4492125	12·845	5·484
166	521·50	21642·43	27556	4574296	12·884	5·495
167	524·65	21904·0	27889	4657463	12·922	5·506
168	527·79	22167·1	28224	4741632	12·961	5·517
169	530·93	22431·8	28561	4826809	13·000	5·528
170	534·07	22698·0	28900	4913000	13·038	5·539
171	537·21	22965·8	29241	5000211	13·076	5·550
172	540·36	23235·2	29584	5088448	13·114	5·561
173	543·50	23506·2	29929	5177717	13·152	5·572
174	546·64	23778·7	30276	5268024	13·190	5·582
175	549·78	24052·8	30625	5359375	13·228	5·593
176	552·92	24328·5	30976	5451776	13·266	5·604
177	556·06	24605·7	31329	5545233	13·304	5·614
178	559·20	24884·6	31684	5639752	13·341	5·625
179	562·34	25164·9	32041	5735339	13·379	5·635
180	565·49	25446·9	32400	5832000	13·416	5·646
181	568·63	25730·4	32761	5929741	13·453	5·656
182	571·77	26015·5	33124	6928568	13·490	5·667
183	574·91	26302·2	33489	6128487	13·527	5·677
184	578·05	26590·4	33856	6229504	13·564	5·687
185	581·19	26880·3	34225	6331625	13·601	5·698

Number.	Circumference.	Area.	Square.	Cube.	Spuare Root.	Cube Root.
186	584·34	27171·6	34596	6434856	13·638	5·708
187	587·48	27464·6	34969	6539203	13·674	5·718
188	590·62	27759·1	35344	6644672	13·711	5·728
189	593·76	28055·2	35721	6751269	13·747	5·738
190	596·90	28352·9	36100	6859000	13·784	5·743
191	600·04	28652·1	36481	6967871	13·820	5·758
192	603·19	28952·9	36864	7077888	13·856	5·768
193	606·33	29255·3	37249	7189057	13·892	5·778
194	609·47	29559·2	37636	7301384	13·928	5·788
195	612·61	29864·8	38025	7414875	13·964	5·798
196	615·75	30171·9	38416	7529536	14·000	5·808
197	618·89	30480·5	38809	7645373	14·035	5·818
198	622·04	30790·7	39204	7762392	14·071	5·828
199	625·18	31102·6	39601	7880599	14·106	5·838
200	628·32	31415·9	40000	8000000	14·142	5·848
201	631·46	31730·9	40401	8120601	14·177	5·857
202	634·60	32047·4	40804	8242408	14·212	5·867
203	637·74	32365·5	41209	8365427	14·247	5·877
204	640·88	32685·1	41616	8489664	14·282	5·886
205	644·03	33006·4	42025	8615125	14·317	5·896
206	647·17	33329·2	42436	8741816	14·352	5·905
207	650·31	33653·5	42849	8869743	14·387	5·915
208	653·45	33979·5	43264	8998912	14·422	5·924
209	656·59	34307·0	43681	9123329	14·456	5·934
210	659·63	34636·1	44100	9261000	14·491	5·943
211	662·87	34966·7	44521	9393931	14·525	5·953
212	666·01	35298·9	44944	9528128	14·560	5·962
213	669·16	35632·7	45369	9663597	14·594	5·972
214	672·30	35968·1	45796	9800344	14·628	5·981
215	675·44	36305·0	46225	9938375	14·662	5·990
216	678·58	36643·5	46656	10077696	14·696	6·000
217	681·73	36983·6	47089	10218313	14·730	6·009
218	684·87	37325·3	47524	10360232	14·764	6·018
219	688·01	37668·5	47961	10503459	14·798	6·027
220	691·15	38013·3	48400	10648000	14·832	6·036
221	694·29	38359·6	48841	10793861	14·866	6·045
222	697·43	38707·6	49284	10941048	14·899	6·055
223	700·57	39057·1	49729	11089567	14·933	6·064
224	703·71	39408·1	50176	11239424	14·966	6·073
225	706·86	39760·8	50625	11390625	15·000	6·082
226	710·00	40115·0	50076	11543176	15·033	6·091
227	713·14	40470·8	51529	11697083	15·066	6·100
228	716·28	40828·1	51984	11852352	15·099	6·109
229	719·42	41187·1	52441	12008989	15·132	6·118
230	722·57	41547·6	52900	12167000	15·165	6·126
231	725·71	41909·6	53361	12326391	15·198	6·135
232	728·85	42273·3	53824	12487168	15·231	6·144
233	731·99	42638·5	54289	12649337	15·264	6·153
234	735·13	43005·3	54756	12812904	15·297	6·162
235	738·27	43373·6	55225	12977875	15·329	6·171
236	741·42	43743·5	55696	13144256	15·362	6·179
237	744·56	44115·0	56169	13312053	15·394	6·188
238	747·70	44488·1	56644	13481272	15·427	6·197
239	750·84	44862·7	57121	13651919	15·459	6·205
240	753·98	45238·9	57600	13824000	15·491	6·214
241	757·12	45616·7	58081	13997521	15·524	6·223
242	760·27	45996·1	58564	14172488	15·556	6·231
243	763·41	46377·0	59049	14348907	15·588	6·240
244	766·55	46759·5	59536	14526784	15·620	6·248
245	769·69	47143·5	60025	14706125	15·652	6·257
246	772·83	47529·2	60516	14886936	15·684	6·265
247	775·97	47916·4	61009	15069223	15·716	6·274
248	779·11	48305·1	61504	15252992	15·748	6·282
249	782·26	48695·5	62001	15438249	15·779	6·291
250	785·40	49087·4	62500	15625000	15·811	6·299

PATENTS OF INVENTION.

Seeing that the validity of a patent depends on novelty in design, and on obtaining the official certificate of acceptance by the Crown Examiner of Patents before details of the invention have been made public, it is evident that steps for obtaining this certificate should be taken as early as possible.

Provisional protection.—To obtain this, which lasts nine months, a provisional specification defining the nature of the invention and the mode in which it is to be carried out, is deposited with the application for provisional pcotection, and the acceptance of these documents by the Crown Examiner of Patents constitutes the protection and fixes the date of the invention. The specification is not open to the public during the above-named nine months which afford time for preparing the final specification and drawings, for developments by manufacture and sale, and for testing the commercial value (or otherwise) of the invention. The provisional secrecy above referred to is especially valuable if foreign patents are contemplated.

The outlay for this—as will be found later on—is quite unimportant, and if the results obtained during the nine months are not satisfactory, no further expense need be incurred.

It is essential that the provisional specification should clearly describe the invention without too closely limiting construction, but rendering evasion difficult, if not impossible. For this reason it is always desirable to consult a competent Patent Agent who will act for the inventor, or as his Trustee, and whose advice on phraseology and mode of procedure is frequently invaluable; he will also notify his client of the dates when payment for renewal of a payment become due, and so save it from lapsing through inadvertence.

Complete specification.—If it is decided to complete the patent, a more detailed specification is lodged, usually with drawings and statement of claims, and these, with the fee then payable, protects the invention for another three years.

In some cases, however, it is better to complete the patent forthwith than on the expiration of the period of provisional protection; the Patent Agent will advise on this point.

Information required.—Personal explanation is, of course desirable, but when this cannot conveniently be given, a written description clearly explaining the invention or improvement, accompanied by sketches, drawings or model, will enable the Patent Agent to decide on the form and manner of application for the desired protection.

Cost of British Patents.—This, naturally, varies in proportion with the intricacy o the invention, the number of drawings (if any) and the quantity of descriptive matter required to clearly explain the details, but if these are of the usual (moderate) quantity the cost will probably be about as follows:

Provisional protection, including tax £3 3 0

Complete patent, including tax to the end of the fourth year ... £8 8 0

Upholding the patent costs £1 more for each year than was paid during the previous year, but it can be allowed to lapse at any time before the full period of 14 years, further expense then ceasing.

PATENTS IN FOREIGN COUNTRIES.—There are fifty-six countries in which patents are granted, but the present purpose will be answered if a few of them are mentioned, especially those in which patents are forfeited if they are not worked in the country itself within a given time, usually three years.

In these countries an inventor seeks remuneration in the sale of his patent rights, whilst in others, where manufacture is not compulsory, he has the advantage of exclusive right to sell his patented products.

The leading conditions in most countries are generally similar to those observed in Great Britain, with however, the above named very important addition of forfeiture if the patent is not worked in the country itself.

Terms of patents.—The period for which patents are granted is usually fifteen years; in some countries, as for instance, the United States of America, Germany, etc. there is strict examination as to novelty and utility, whilst in others no such examination is imposed.

In all cases application for Foreign Patents should be made before the final specification o the British patent is issued; a further reason for this is that a foreign patent usually lapses on the same date as the British patent.

COST OF FOREIGN PATENTS.—The following figures are based on the assumptions indicated at page 320, see "Cost of British Patents," and they include the cost of the necessary translations :

APPROXIMATE COST OF COLONIAL AND FOREIGN PATENTS.

	£	s.	d.		£	s.	d.
AUSTRALIA—				**FRANCE**	12	0	0
New South Wales	18	0	0	**GERMANY**	15	0	0
Queensland ...	18	0	0	**INDIA**	22	0	0
South Australia ...	18	0	0	**ITALY**	15	0	0
Victoria	16	0	0	**LUXEMBOURG** ...	12	0	0
West Australia ...	16	0	0	**MEXICO**	50	0	0
New Zealand ...	16	0	0	**NORWAY**	13	0	0
Tasmania	20	0	0	**PORTUGAL**	30	0	0
AUSTRIA	15	0	0	**RUSSIA**	18	0	0
BELGIUM	8	0	0	**SPAIN**	18	0	0
BRAZIL	40	0	0	**SWEDEN**	15	0	0
CANADA	20	0	0	**SWITZERLAND** ...	16	0	0
CAPE of GOOD HOPE	30	0	0	**TURKEY**	25	0	0
CEYLON	25	0	0	**UNITED STATES OF AMERICA**	20	0	0
CHILE	80	0	0				
DENMARK	15	0	0				

REGISTRATION OF DESIGNS gives protection for five years and can be effected at a cost, for each registration, of about £2 2 0

This form of protection applies more especially to a pattern, shape or ornamental design, and is rarely of value in connection with mechanical or scientific inventions which require modification in arrangement of parts, etc.

This can be done without invalidating letters patent, but not so under registration.

TRADE MARKS.—Registration of words, figures, letters, or a combination of these with a distinctive device, confers on those who have obtained it the sole right of using such mark for fourteen years. Application should be made through an Agent who has experience in such matters.

The cost of registration, including completion, is usually about... ... £4 4 0